Copyright, 1935, by the AMERICAN SOCIETY OF NAVAL ENGINEERS.

JOURNAL
OF THE
AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. 47. MAY 1935. No. 2

The Society as a body is not responsible for statements made by individual members

COUNCIL OF THE SOCIETY
(Under whose supervision this number is published).

Admiral WILLIAM H. STANDLEY, U.S.N. — Captain HENRY WILLIAMS, (C.C.) U.S.N.
Captain N. H. WRIGHT, U.S.N. — Commander H. N. PERHAM, U.S.C.G.
Captain B. H. BRUCE, U.S.N. — Mr. JOHN F. NICHOLS
Commander S. S. KENNEDY, U.S.N. — Mr. W. M. CORSE
Commander C. S. GILLETTE, U.S.N.

# AIR HEATERS AND ECONOMIZERS FOR MARINE SERVICE.

By T. B. STILLMAN.*

The fundamental purpose of air heaters and economizers is to recover heat from gases leaving boilers which it would not be feasible to recover with the boilers alone. With increasing steam pressures and temperatures, the commercial desirability of using air heaters or economizers is correspondingly increased. In a similar manner, increased fuel costs will frequently justify the use of such additional equipment when relatively cheap fuel may not. Like other supplementary equipment which may be used aboard ship, which is not primarily essential for its operation, air heaters and economizers should only be used when their presence is justified on (*a*) merchant ships, by a reduction in fuel costs which will more than pay for the increased carrying and operating

* Engineering Department, Babcock & Wilcox Company, New York, N. Y.

charges, and on (*b*) Navy ships, when the increased steaming radius more than counterbalances the increased weight and complication.

The reason air heaters and economizers are able to extract more heat from the relatively low temperature gases than corresponding boiler surface is because of the lower average tube temperatures existing in the air heaters and economizers, resulting in a correspondingly greater temperature difference between the gases and tubes than can occur with boiler surfaces. Because of this, it is quite common to have the gases leaving air heaters or economizers under full power conditions at temperatures below that of the boiler tubes. In general, it may be said that, assuming relatively good combustion conditions, for each 42 degrees F. reduction in uptake gas temperatures, the "boiler efficiency" will increase 1 per cent with oil fuel. For coal fuel a corresponding 1 per cent increase in efficiency will occur with each 35 degrees F. reduction in uptake gas temperature.

Although both air heaters and economizers abstract heat from uptake gases and return it to the boiler system, the procedure followed in the two cases is radically different. In the case of air heaters, the heat taken from the gases is transmitted to the combustion air on the way to the fuel burners, appearing as sensible heat in the furnace gases which has to be re-absorbed by the heating surfaces. The heat taken out of the gases by the economizers goes directly into the feedwater on its way to the boiler and does not again have to be re-absorbed by any of the heating surfaces. Both systems have distinct advantages and disadvantages which will be pointed out later.

## AIR HEATERS—TYPES.

There are three general types of air heaters that are used for extracting heat from uptake gases, namely, (1) tubular, (2) plate, and (3) regenerative.

Regardless of the claims put forward from time to time for these different types in the stationary power plant field, the fact remains that in marine service (both American and European) where weight, space, and minimum upkeep charges are paramount con-

siderations, the tubular type of air heater is used almost exclusively, this in spite of the fact that, for a given performance when new, the tubular heaters generally cost a little more than the other types. Accordingly this presentation will be confined to air heaters of the tubular type.

Tubular heaters may be of two general classes (*a*) those with gases inside the tubes and (*b*) those with gases outside the tubes. The latter may again be subdivided into those using tubes with circular cross section and those having diamond shaped or " stream flow " cross section.

It is always desirable, when space conditions permit, to have the air heaters counter flow, that is, have the air and gas enter the heater at opposite ends, as this increases the mean temperature difference between them. It is also desirable in most cases to have the medium on the outside of the tubes cross the tubes in two or more " passes " to improve the scrubbing action and corresponding heat transfer rate. If the gases are carried inside the tubes, it is customary to have the tubes vertical or nearly so, to prevent, as far as possible, loose soot deposits, etc., from remaining inside the tubes. It is not usually customary to use air heater tubes less than two inches in diameter due to the increased cost and to the excessive air or gas resistance through them which would occur with the smaller sizes.

Air heaters have been used for a great many years, the familiar Howden system on Scotch boilers probably having done more to keep that type of boiler afloat than any merits possessed by the boiler itself. In this case, the air heater not only reduced the temperatures of the uptake gases to a reasonable figure, but also, due to the preheating of the air, had an appreciable effect on improving the combustion conditions existing in the relatively small and low temperature furnaces inherent in this type of boiler. Figure 1 shows the customary type of air heater fitted to Scotch boilers, the gas being on the inside of the tubes—the air making a single pass only on the outside.

Figure 2 shows an air heater located above a marine header type boiler with the air on the inside and the gas making three passes on the outside of the tubes. The heated air passes down the

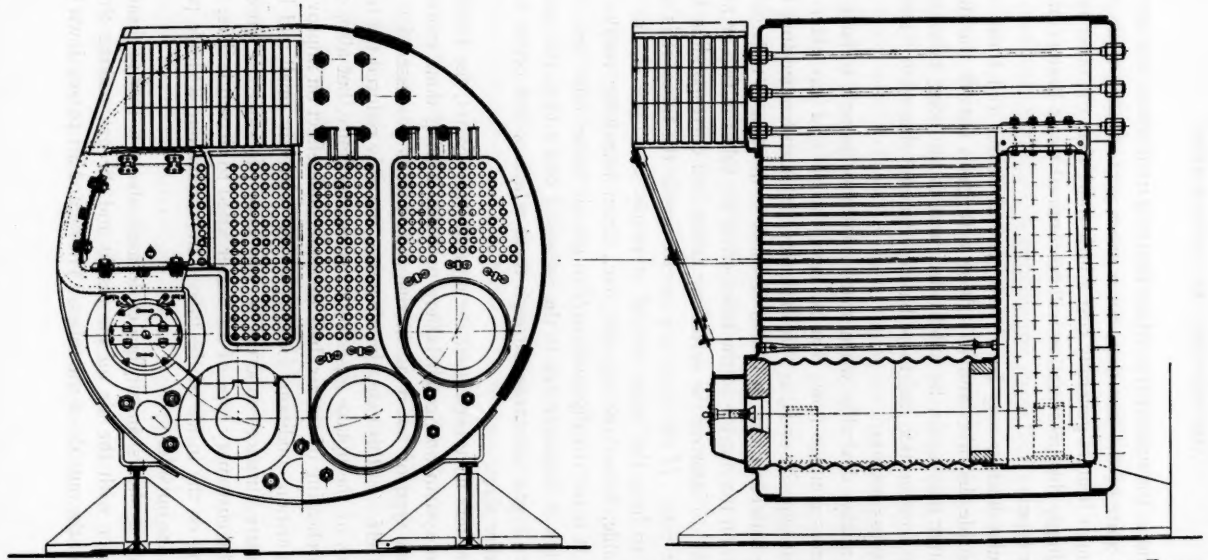


FIGURE 1—VERTICAL TYPE AIR HEATER FITTED TO SCOTCH BOILER, GASES INSIDE WITH AIR MAKING SINGLE PASS OUTSIDE OF TUBES. AIR HEATING SURFACE IS 26.5 PER CENT OF BOILER SURFACE.

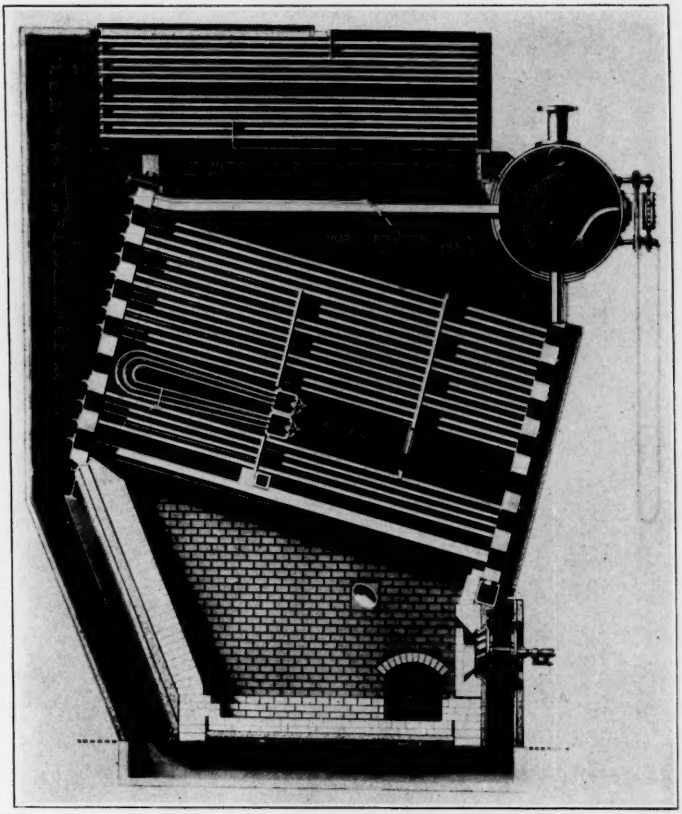


FIGURE 2—HORIZONTAL TUBE AIR HEATER FITTED TO HEADER TYPE MARINE BOILER, GASES MAKING THREE PASSES OUTSIDE WITH AIR INSIDE OF TUBES. AIR HEATING SURFACE IS 46.3 PER CENT OF BOILER PLUS SUPERHEATER SURFACE.

back of the boiler under the furnace and up to the burners. The gas swept surfaces of the air heater in this case are kept clean the same way as the boiler surfaces—with rotating soot blowers properly located in the tube bank.

Figure 3 is the construction which was employed in placing air heaters above a three drum type of boiler in a merchant ship. In this case the gas is inside the tubes, the air making two passes on the outside. The air enters and leaves the heater at the back of the unit, passing behind the boiler then under the furnace floor, and up to the burners. The relatively infrequent cleaning necessary for these tubes is accomplished by sending men into the uptake above the air heaters with suitable brushes when the boiler is shut down.

Figure 4 illustrates tubular air heaters above a three drum boiler with the air inside the tubes, the gas passing straight through vertically on the outside of the tubes. The heated air comes directly from the front of the air heater and passes through a short duct downward to the burners. This type of heater may be either single pass or two pass on the air side, depending upon the number and diameter of tubes used, and allowable air resistance through them.

Figure 5 shows the construction used to get an air heater in a badly restricted space above a three drum boiler. Air inside the tubes, gas outside, both single pass. The heated air passes downward behind the boiler, under the furnace floor and then up to the burners.

Figure 6 shows the air heater construction used in a destroyer of the English Navy having gas on the inside and air on the outside of the tubes. The heater is single pass both sides, the air going from the front to the back through the heater and then forward to the oil burners through the double casing under the furnace as well as that above the lower drums of the boiler. This installation is of particular interest in view of the use of "stream flow" shaped tubes, reducing to a minimum the air resistance for a given heat transfer rate.

Figure 7 shows one of the air heaters used on the S. S. *Empress of Britain*. The gas is inside the tubes with the air making seven passes around the tubes on the outside. The heated air is delivered

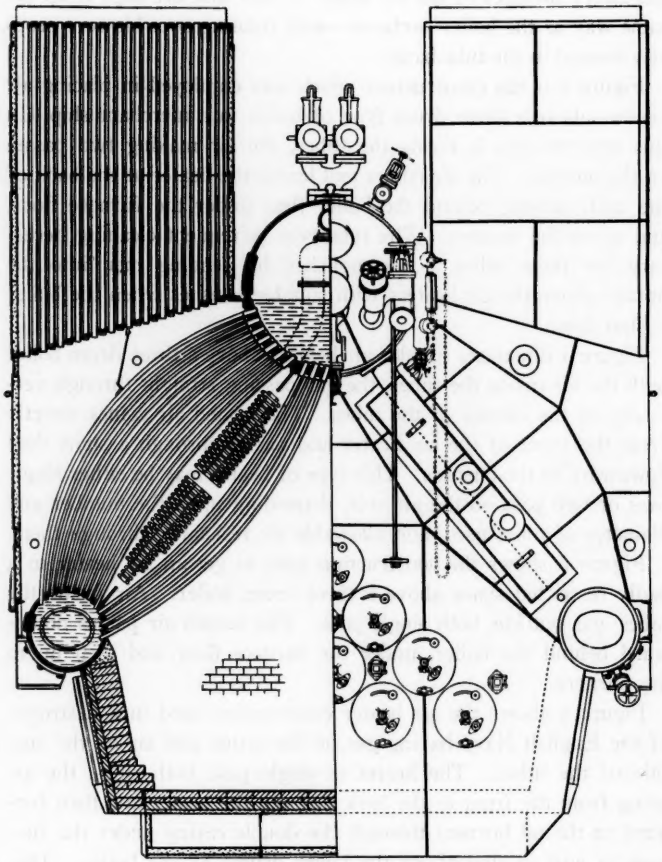



FIGURE 3—VERTICAL TUBE AIR HEATER FITTED TO THREE-DRUM MARINE BOILER. GASES INSIDE WITH AIR MAKING TWO PASSES OUTSIDE OF TUBES. AIR HEATER SURFACE IS 63.0 PER CENT OF BOILER PLUS SUPERHEATER SURFACE.

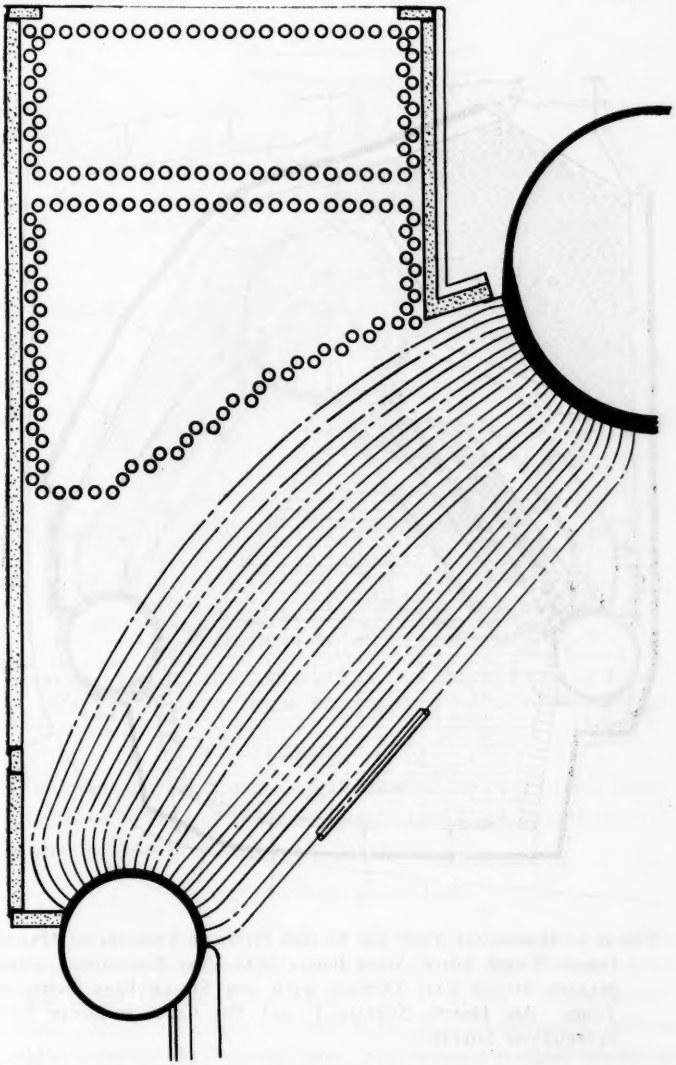


FIGURE 4—HORIZONTAL TUBE AIR HEATER FITTED TO THREE-DRUM MARINE BOILER. GASES MAKING SINGLE PASS OUTSIDE WITH AIR MAKING ONE OR MORE PASSES INSIDE OF TUBES. AIR HEATER SURFACE, 79.4 PER CENT OF BOILER PLUS SUPERHEATER SURFACE.

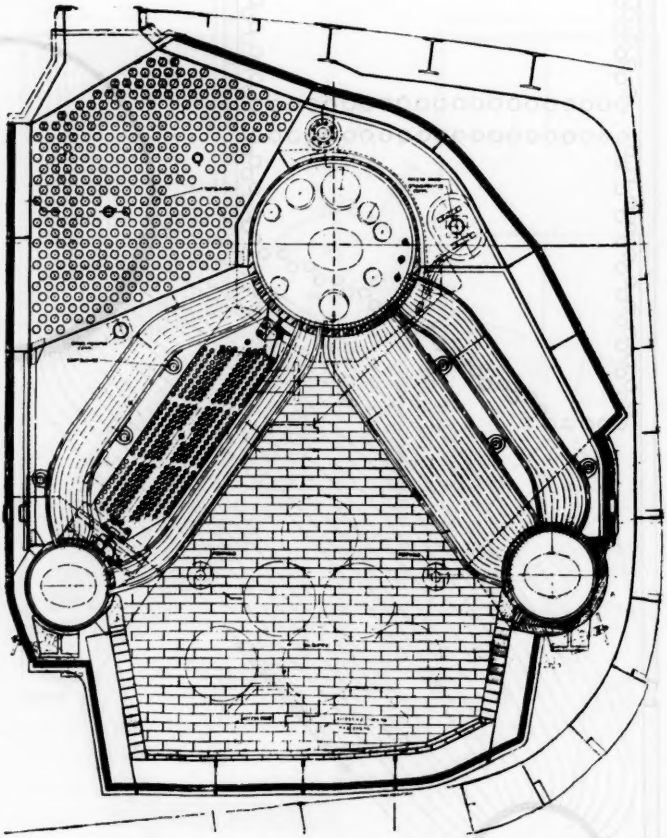


FIGURE 5—HORIZONTAL TUBE AIR HEATER FITTED TO THREE-DRUM MARINE BOILER WHERE SPACE ABOVE BOILER WAS VERY RESTRICTED. GASES MAKING SINGLE PASS OUTSIDE WITH AIR SINGLE PASS INSIDE OF TUBES. AIR HEATER SURFACE IS 31.5 PER CENT OF BOILER PLUS SUPERHEATER SURFACE.

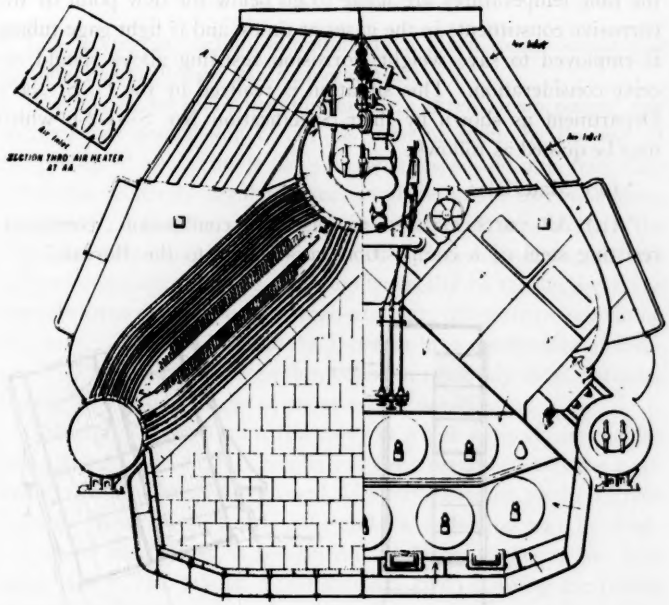


FIGURE 6—"STREAM FLOW" SHAPED TUBE AIR HEATER FITTED TO THREE-DRUM BOILER. GASES INSIDE TUBES WITH AIR MAKING SINGLE PASS OUTSIDE.

to a double casing surrounding all sides of the boiler from which it is delivered to burners at the front. This is the largest (23,943 square feet) air heater ever installed aboard ship.

### AIR HEATERS—MATERIALS.

As far as we have been able to determine, all air heaters afloat at the present time are made of steel with the single exception of those in the German Coast Guard Cutters of the "Hindenberg" class. These are made of very light gage Monel-metal and in addition are of the "stream flow" type similar to those shown in Figure 6. Corrosion due to sulphuric acid is an ever present factor in the life of air heater tubes, especially at the air inlet end, where

the tube temperatures are liable to go below the dew point of the corrosive constituents in the gases at times, and if light gage tubing is employed to save weight, corrosion resisting alloys should receive consideration. This situation is realized by the U. S. Navy Department as shown by their Specification No. S-51-2-n which may be quoted as follows:

"(1) Materials:

"(a) All parts exposed to gases of combustion; corrosion-resisting steel of a composition satisfactory to the Bureau."

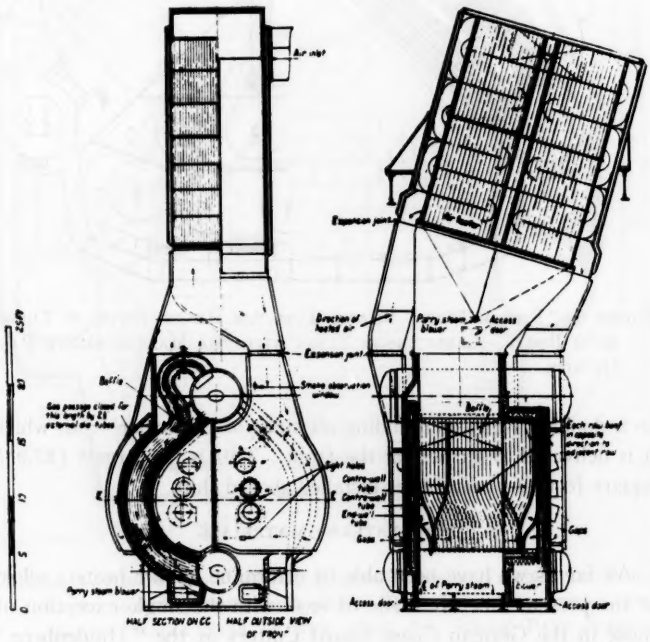


FIGURE 7—LARGE AIR HEATER FITTED TO TWO-DRUM MARINE BOILER. GASES INSIDE WITH AIR MAKING SEVEN PASSES OUTSIDE OF TUBES. AIR HEATER SURFACE, 224.2 PER CENT OF BOILER PLUS SUPERHEATER SURFACE.

AIR HEATERS—ADVANTAGES.

(1) Saving in fuel consumption for a given steam output due to reduction in uptake gas temperatures.

(2) Saving in fuel consumption for a given steam output due to improved combustion conditions brought about by the use of the preheated air. This is likely to be an especially important factor in the relatively small furnaces available under marine boilers. In general, it may be said that the more difficult it is to burn the fuel efficiently, the greater the possible fuel savings due to the use of preheated air. This is due fundamentally to the higher flame temperatures obtainable with preheated air, other items remaining the same. This also leads to the fact that high combustion efficiencies may be obtained with preheated air in relatively small furnaces having a large percentage of water cooled surface.

Although there are but a few cases in which a direct, dependable comparison based on test results has been made between the combustion results secured with and without preheated air in a given furnace, there are such available, and the following may be cited:

(*a*) In the United States Bureau of Mines Bulletin, No. 214, pages 239 to 250, tabulated test data are given showing the results secured with and without an air heater on a Scotch boiler using oil fuel. Figure 8 shows in curve form the respective efficiencies secured at different rates under the two conditions as well as the portion of the improvement that was due directly to reduction of the uptake gas temperatures and that portion which was due to the improved combustion conditions. It is interesting to note that at the lower rates of operation, where it is usually more difficult to secure satisfactory combustion conditions in these relatively "cold" Scotch boiler furnaces with atmospheric air, the preheated air showed the greatest benefit, although at no rate of operation was the improvement in "Boiler Efficiency" due to improved combustion, less than 1 per cent.

(*b*) In the February, 1924, issue of "Mechanical Engineering" a paper was presented by Mr. C. W. E. Clarke entitled "Boiler-Test Results with Preheated Air" giving the test results secured at the Colfax Station of the Duquesne Light Company using a

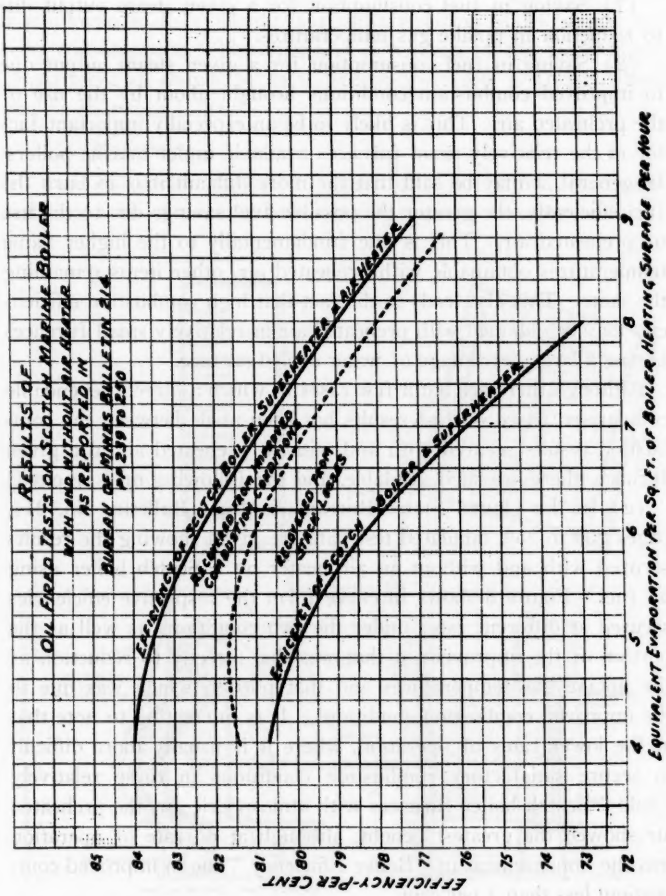

RESULTS OF
OIL FIRED TESTS ON SCOTCH MARINE BOILER
WITH AND WITHOUT AIR HEATER
AS REPORTED IN
BUREAU OF MINES BULLETIN 214
PP 219 TO 230
EFFICIENCY OF SCOTCH BOILER, SUPERHEATER & AIR HEATER
EFFICIENCY OF SCOTCH BOILER & SUPERHEATER
RICHARD'S SMOKELESS COMBUSTION CHAMBER
REDUCED MAIN STEAM LOSSES
EFFICIENCY-PER CENT
EQUIVALENT EVAPORATION PER SQ. FT. OF BOILER HEATING SURFACE PER HOUR
85 84 83 82 81 80 79 78 77 76 75 74 73 72
4 5 6 7 8 9

FIGURE 8—BOILER EFFICIENCIES SECURED WITH AND WITHOUT AN AIR HEATER FITTED TO A SCOTCH BOILER USING OIL FUEL.

Babcock & Wilcox boiler, stoker fired, with and without an air heater. Figure 9 shows the respective efficiencies secured as well as the portion of the improvement that was due to reduction in uptake gas temperature and that portion due to improved combustion conditions. The reduction of the per cent combustible in the ash due to the use of the air heater was a large proportion of the latter.

From the above it will be realized that, depending upon the fuel used and methods of firing it, fuel savings, due to the use of air heaters improving combustion conditions, may at times be as great as those due to the reduction in gas temperatures through the air heaters.

(3) If pulverized coal is used for fuel, suitably preheated primary air should be available to the pulverizers. Air heaters assure an ample supply of this, without recourse to steam air heaters for this purpose.

(4) Air heaters may readily be fabricated at a relatively low cost per square foot of heating surface, as they do not require the care essential in the fabrication of pressure parts.

(5) Finally, if at any time, due to poor workmanship or corrosion, minor leaks develop in an air heater, it is a matter of relatively small moment, and does not require the shutting down of the boiler unit, as must be done when a leak occurs in any high pressure portion of the system.

### AIR HEATERS—DISADVANTAGES.

(1) Air heaters are relatively large and heavy for the percentage of heat they absorb from the uptake gases. In addition to the heaters themselves, insulated ducts from the heaters to the burners are necessary.

(2) The use of air heaters always introduces an appreciable increase in fan load. This is due not only to the added resistance through the air and gas sides of the air heater, as well as that through the air ducts, but also to the added air resistance through the fuel burners. For a given poundage of air burned, the air resistance through the burners goes up almost directly as the absolute temperature of the air entering the burners. For exact figures

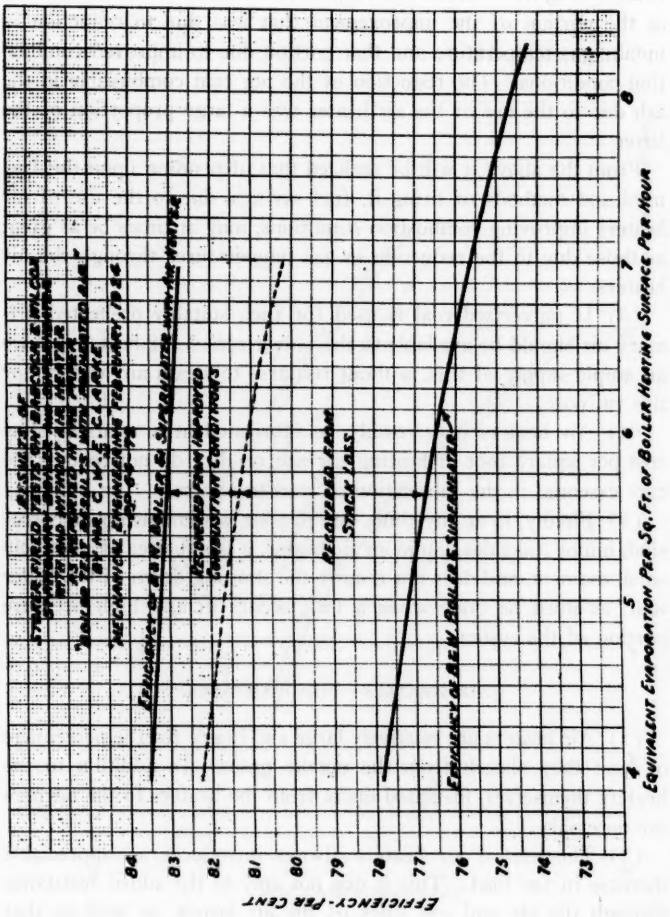



FIGURE 9—BOILER EFFICIENCIES SECURED WITH AND WITHOUT AN AIR HEATER FITTED TO A STOKER-FIRED BABCOCK & WILCOX BOILER.

regarding this increased fan load for a given set of conditions see Table No. 1.

(3) As previously mentioned, increasing the air temperature to the burners increases the furnace temperatures, with a corresponding shortening of the life of furnace refractories and an increase in the tube losses in the furnace row of boiler tubes for a given scale and rating condition. If coal is the fuel used, preheated combustion air increases the trouble from slag on boiler tubes, overheating of grates, matting of coal, and clinkers. The practical result of this (especially in coal fired units) has been to increase the percentage of cooling surface in a furnace to counteract the undesirable effects which would otherwise take place because of the increased air temperatures.

(4) The additional draft loss through the gas side of an air heater may require that the boiler be double cased, placed in a closed fireroom, or that an induced draft fan be used, to prevent gas leakage into the spaces occupied by the operating personnel; whereas the same boiler without an air heater could probably be operated satisfactorily in an open fireroom with nothing but a double front surrounding the fuel oil burners, the natural draft of the stack taking care of the gas resistance through the boiler tube bank.

(5) Additional soot blowers and a corresponding increase in steam consumption by them (with its attendant loss of fresh water from the ship) will be required by an air heater installation, compared to a boiler installation without them. For exact figures regarding this comparison, see Table No. 1.

## ECONOMIZERS—TYPES.

Economizers may be divided into two general types—(1) those using bare tubes and (2) those using extended surface. The former of these may again be divided into (1) independent and (2) integral. Integral economizers may be further divided into (1) steaming and (2) non-steaming economizers.

Both the bare tube and extended surface economizers have found general application in the marine field, but the latter have proved less satisfactory with coal than with oil fuel, due to the excessive

tendency of the dirt in the products of combustion of the coal to plug the openings between the fins of the extended surface type.

As in the case of air heaters, it is preferable to build economizers counterflow between the gas and water due to the increased temperature differences. In the case of steaming economizers it is desirable to have the flow of steam and water in the economizer in an upward direction, regardless of the direction of flow of the gases.

Figure 10 shows an economizer of the bare tube independent type located above a marine header type boiler.

Figure 11 illustrates the application of extended surface economizers above a three drum type of marine boiler. In this particular

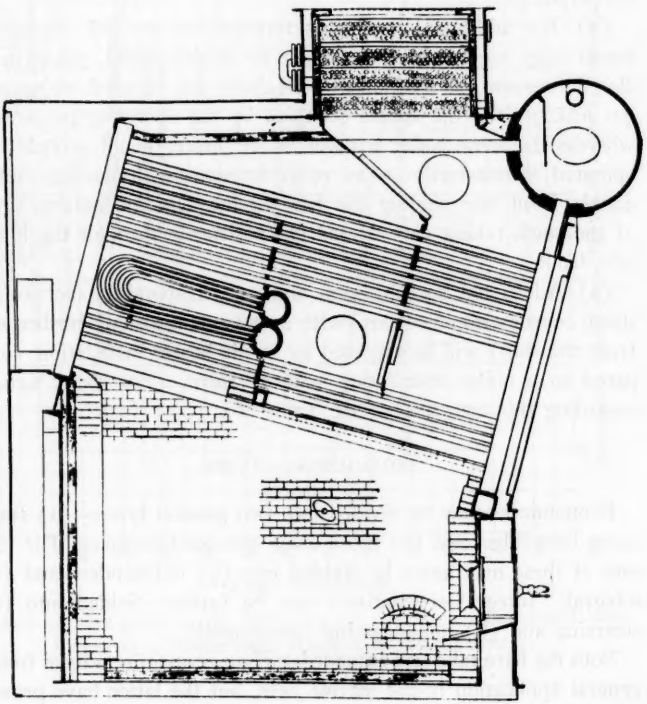


FIGURE 10—BARE TUBE ECONOMIZER FITTED TO A HEADER TYPE MARINE BOILER. THE ECONOMIZER SURFACE IS 36.8 PER CENT OF THE BOILER PLUS SUPERHEATER SURFACE.

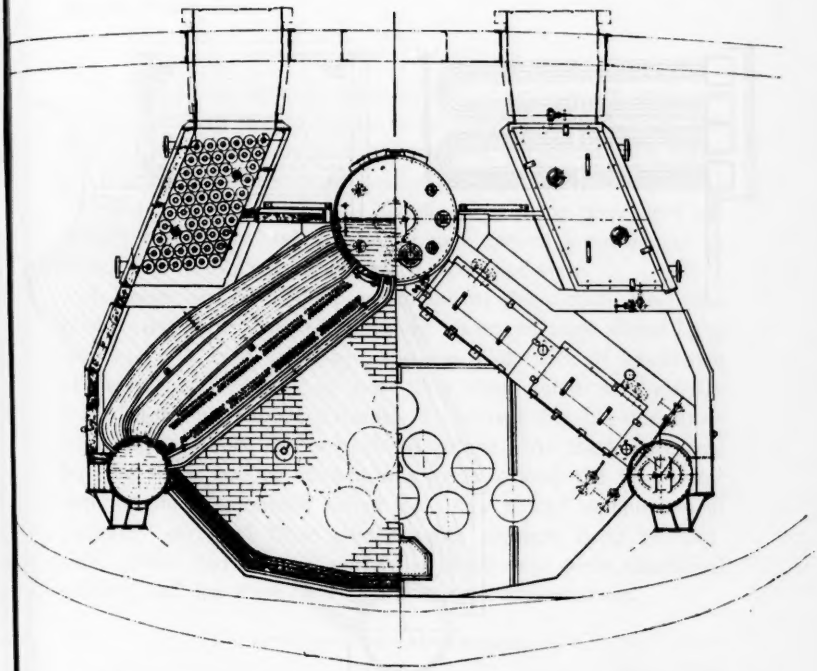


FIGURE 11—EXTENDED SURFACE TYPE ECONOMIZER FITTED TO THREE-DRUM MARINE BOILER. THE ECONOMIZER SURFACE IS 64.4 PER CENT OF THE BOILER PLUS SUPERHEATER SURFACE.

installation, which is oil fired, the extended surface is made up of aluminum to save weight, compared to a cast iron construction.

Figure 12 shows a bare tube economizer of the independent type located above a three drum marine type boiler.

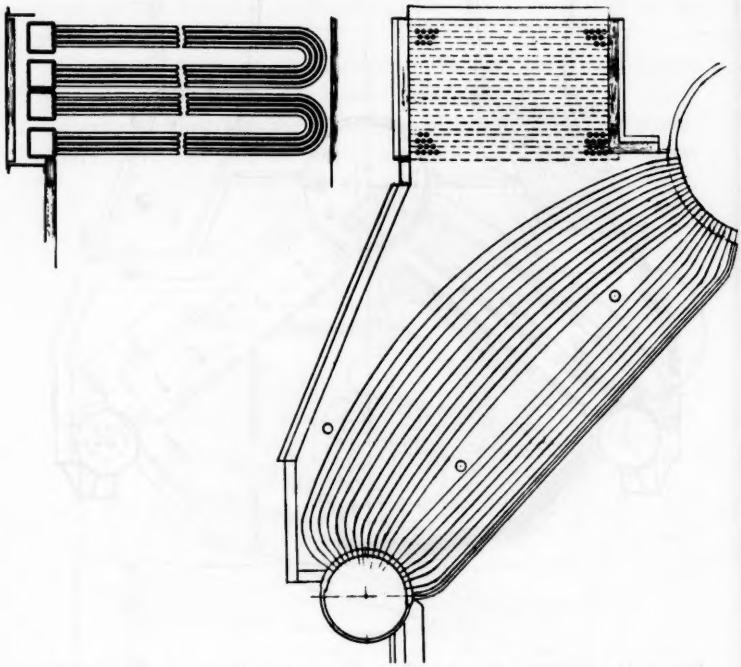


FIGURE 12—BARE TUBE ECONOMIZER FITTED TO THREE-DRUM MARINE BOILER. THE ECONOMIZER SURFACE IS 36.5 PER CENT OF THE BOILER PLUS SUPERHEATER SURFACE.

Figure 13 shows an integral economizer unit applied to a three drum Express boiler. As the name indicates, the economizer in this case is an integral part of the boiler. This is the type of economizer unit which may readily be made of the steaming design, as the water in the last pass is rising toward a free discharge into the boiler drum.

### ECONOMIZERS—MATERIALS.

To date all economizer tubes in marine service are made of carbon steel, but due to the corrosion attacks, both internal and external, to which these units are exposed, consideration is being given at the present time to making the tubes of economizers of corrosion resisting materials. Investigations along these lines are already under way and may result in a radical improvement in these units from a practical operating point of view.

As an illustration of the practical side of this picture, steel tube economizers were installed above the boilers of some Great Lake steamers over forty years ago, and due to the lack of knowledge of deaerating feedwater in those days, these tubes were quickly corroded through from the inside. To prevent this, the steel tubes were replaced with others made of copper. As these were coal burning ships, and no attempt was made to keep the feed water entering the economizers above the "dew point," sulphuric acid promptly corroded these copper tubes through from the outside. After that the economizers on these ships were abandoned entirely, and the ships continued in service without them.

### ECONOMIZERS—ADVANTAGES.

(1) Same as (1) under Air Heaters.

(2) Economizers are relatively compact for the percentage of heat absorbed from the uptake gases due to the relatively low average tube temperature. It is seldom commercially desirable to have the heating surfaces in economizers greater than about 40 per cent of the boiler and superheating surface when bare tubes of small diameter are used. An exception to this occurs in the case of steaming economizers when it is frequently desirable to use appreciably larger percentages of economizer surface.

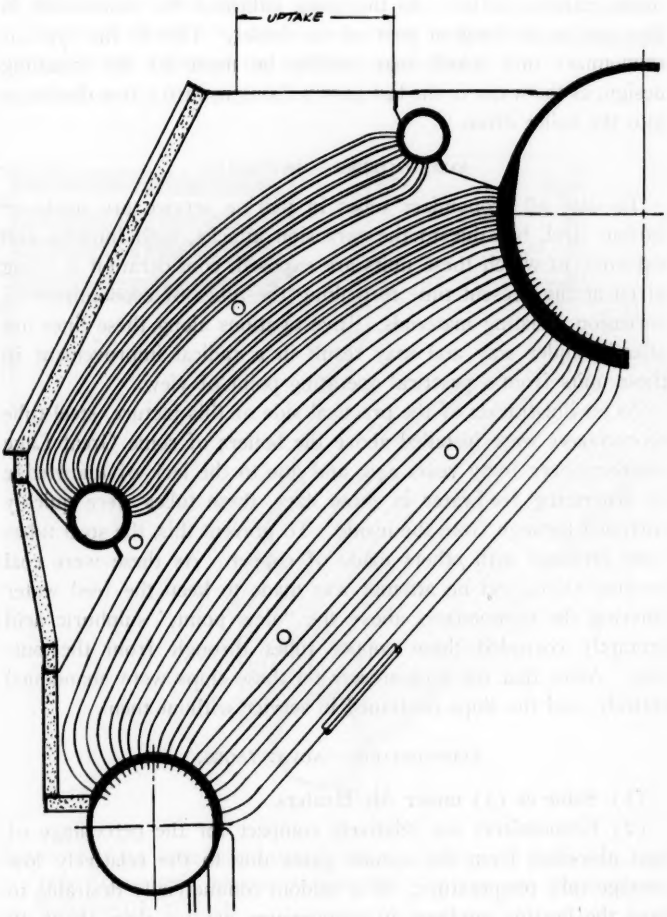



FIGURE 13—BARE TUBE INTEGRAL ECONOMIZER FITTED TO A THREE-DRUM MARINE BOILER. THE ECONOMIZER SURFACE IS 44.6 PER CENT OF THE BOILER PLUS SUPERHEATER SURFACE.

(3) If small diameter (approximately 1-inch) tubes are used, very compact and relatively light weight economizers may be built for a given performance. If larger tubes (2-inch or greater) are employed it is necessary to use extended surface made of a light weight alloy to retain the compact and light weight features.

### ECONOMIZERS—DISADVANTAGES.

(1) Items (4) and (5) under "Air Heaters—Disadvantages," apply equally to economizers. Item (2) under the same heading applies to a lesser extent to economizer installations.

(2) Special vigilance must be exercised with the feedwater treatment in economizer installations and extra precautions taken at all times to keep the oxygen content in the feedwater to the economizers to less than .03 cubic centimeters per litre to avoid excessive internal corrosion with its attendant rapid loss of economizer tubes due to pitting.

(3) As in the case of air heaters—all parts of the tubes of an economizer must be kept above the "dew point" of the corrosive constituents in the gases while a unit is in service to prevent corrosion due to sulphuric acid attacking the external surfaces of the tubes.

(4) Economizers add greatly to the number of high pressure joints per boiler unit. Frequently there are more gasketed joints in one economizer than in all the boiler units in the ship. On the average, greater care is necessary in making up joints, either expanded or gasketed, in an economizer than is the case with similar joints, subjected to the same pressure, in a boiler. This is because of the sudden temperature changes to which the units of an economizer may be subjected while in service, due to changes in load while maneuvering, etc.

### COMPARISON OF AIR HEATERS AND ECONOMIZERS FOR MARINE SERVICE.

From the above statements of advantages and disadvantages of air heaters and economizers for marine service, the following direct comparative general summary may be made.

(1) For a given reduction in uptake gas temperature an air heater imposes a greater fan load than does the economizer.

(2) An air heater occupies a greater volume and weighs more than a corresponding properly designed economizer.

(3) The air heater provides higher furnace temperatures for a given operating condition, leading to shorter life for the furnace refractories, and increased tube losses in the furnace row for a given scale condition in the feed water. As against that the increased furnace temperatures assure an improved combustion condition in the average marine boiler furnace, with a corresponding reduction in fuel consumption for a given steam output. The more difficult it is to burn the fuel efficiently the greater the benefit to be expected from these higher furnace temperatures.

(4) The air heater permits the use of relatively high stage turbine bleeding with a corresponding increase in overall thermal efficiency of the ship without such bleeding adversely affecting the efficiency of boiler and air heater. Corresponding high stage bleeding with an economizer will result in reduction of boiler and economizer efficiency or a radical increase in size and weight of economizer to hold a constant boiler efficiency.

(5) Minor leaks in an air heater due to corrosion or otherwise are of no practical importance in the operation of the unit. Even minute leaks in an economizer require shutting down of the boiler unit until such leaks are stopped.

(6) No greater care is necessary in the feed water treatment from an oxygen content point of view with an air heater than is required with a boiler not so fitted. In this connection it is to be remembered, however, that as steam pressures are increased, correspondingly less oxygen content can be allowed in the feed water, if corrosion and pitting of the boiler surfaces is to be avoided. With an economizer very special precautions must be taken at all times to insure that the oxygen content of the feed water entering the same does not exceed .03 cubic centimeter per liter.

(7) The additional gas resistance introduced by either an air heater or an economizer will, in the average ship, require that the boiler unit be double air cased, fitted with an induced draft fan, or placed in a closed fireroom, where a boiler unit alone might not require such additional construction or equipment.

COMPARISON O

Boiler Heating Surface in Two Units ..... 8406 Sq. Ft.
Super Heating Surface in Two Units ..... 1960 Sq. Ft.
Total Boiler and Superheating Surface Used in all Studies .... 10366 Sq. Ft.

Two M

Air

| Study Number | DESCRIPTION OF UNITS | Air Heaters | | Economizers | | Total heating surface of two complete boiler units Sq. Ft. | Percentage increase in total heating surface Percent | Ad weig |
|---|---|---|---|---|---|---|---|---|
| | | Diameter of tubes inches | Heating surface Sq. Ft. | Diameter of tubes inches | Heating surface Sq. Ft. | | | Air heaters Pounds |
| 1 | Boilers and superheaters | ..... | ..... | ..... | ..... | 10366 | ..... | ..... |
| 2 | With vertical tube air heaters, gas inside tubes single pass, air outside tubes two pass. (Similar to figure No. 3) | 2 | 9820 | ..... | ..... | 20186 | 94.7 | 6168 |
| 3 | With horizontal tube air heaters, gas outside tubes single pass, air inside tubes three pass. (Similar to figure No. 4) | 2½ | 13470 | ..... | ..... | 23836 | 130.0 | 7352 |
| 4 | With horizontal tube air heaters, gas outside tubes single pass, air inside tubes single pass. (Similar to figure No. 4) | 1 | 13016 | ..... | ..... | 23382 | 125.5 | 5828 |
| 5 | With double element economizers. (Similar to figure No. 12) | ..... | ..... | 1 | 2050 | 12416 | 19.8 | ..... |
| 6 | With return bend stationary type economizers | ..... | ..... | 2 | 3180 | 13546 | 30.7 | ..... |
| 7 | With extended surface (aluminum) economizers. (Similar to figure No. 11) | ..... | ..... | 2 | 4144 | 14510 | 40.0 | ..... |
| 8 | With integral economizers. (Similar to figure No. 13) | ..... | ..... | 1 | 5416 | 15782 | 52.2 | ..... |
| 9 | With combination of integral economizers in series with double element economizers. (Similar to figure No. 12 combined with No. 13) | ..... | ..... | 1 | 7466 | 17832 | 72.0 | ..... |
| 10 | With combination of integral economizers and horizontal tube air heaters, gas outside tubes single pass, air inside tubes two pass. (Similar to figure No. 4 combined with No. 13) | 2½ | 5596 | 1 | 2632 | 18594 | 79.4 | |

NOTES:

† Approximate values.

* If feed water temperature in No. 1 study is increased to 340°F. by means of turbine steam bled to a feed w total steam generated per hour by the two boiler units will be increased to 74700 pounds without changing in the above table. (7975 pounds of steam at 200 lb. pressure and 620°F. bled per hour for this purpose.)

## TABLE No. 1

### PARISON OF WEIGHTS, VOLUMES AND PERFORMANCES OF TWO MARINE BOILERS AND SUPERHEATERS FITTED WITH AIR HEATERS AND/OR ECONOMIZERS

Steam Pressure
Steam Temper
Sytem of Draf
Oil Fired—Six
Total Weight O

| | Additional weight due to | | Total wet weight of two complete boiler units Pounds | Percentage increase in total weight Percent | Additional volume due to | | Total Volume occupied by two complete boiler units Cu. Ft. | Percentage increase in total volume Percent | Temperature of feed water entering unit °F. | Temperature of air entering burners °F. | Temperature of gases entering uptakes °F. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Air heaters Pounds | Economizers wet Pounds | | | Air heaters Cu. Ft. | Economizers Cu. Ft. | | | | | |
| .... | ..... | ..... | 173660 | ..... | ..... | ..... | 4022 | ..... | 220° | 90 | 700 |
| .7 | 61680 | ..... | 235340 | 35.5 | 2160 | ..... | 6182 | 53.7 | 220‡ | 450 | 400 |
| .0 | 73520 | ..... | 247180 | 42.3 | 1964 | ..... | 5986 | 48.8 | 220‡ | 450 | 400 |
| .5 | 58280 | ..... | 231940 | 33.6 | 1550 | ..... | 5572 | 38.5 | 220‡ | 450 | 400 |
| .8 | ..... | 23540 | 197200 | 13.6 | ..... | 230 | 4252 | 5.7 | 220 | 90 | 400 |
| .7 | ..... | 69240 | 242900 | 39.9 | ..... | 1444 | 5466 | 35.9 | 220 | 90 | 400 |
| .0 | ..... | 19380† | 193040† | 11.2† | ..... | 228 | 4250 | 5.7 | 220 | 90 | 400 |
| .2 | ..... | 42060 | 215720 | 24.2 | ..... | 534 | 4556 | 13.3 | 220 | 90 | 400 |
| .0 | ..... | 65920 | 239580 | 37.9 | ..... | 848 | 4870 | 21.1 | 340 | 90 | 400 |
| .4 | 56900 | | 230560 | 32.8 | 1596 | | 5618 | 39.7 | 340 | 282 | 400 |

to a feed water heater, the
t changing any other data
purpose.)

‡ If feed water temperature in No. 2, 3 and 4 studies is increased to 340° F
heater the total steam generated per hour by the two boiler units will be
other data in the above table.
(8710 pounds of steam at 200 lb. pressure and 620°F. bled per hour for th

3406 Sq. Ft.
1960 Sq. Ft.
0366 Sq. Ft.

# TABLE No. 1

## Comparison of Weights, Volumes and Performances of Two Marine Boilers and Superheaters fitted with Air Heaters and/or Economizers

| Air Heaters | | Economizers | | Total heating surface of two complete boiler units Sq. Ft. | Percentage increase in total heating surface Percent | Additional weight due to | | Total wet weight of two complete boiler units Pounds | Percentage increase in total weight Percent | Additional volume due to | | Total Volume occupied by two complete boiler units Cu. Ft. | Percentage increase in total volume Percent | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| meter of ubes ches | Heating surface Sq. Ft. | Diameter of tubes inches | Heating surface Sq. Ft. | | | Air heaters Pounds | Economizers wet Pounds | | | Air heaters Cu. Ft. | Economizers Cu. Ft. | | | |
| ..... | ..... | ..... | ..... | 10366 | ..... | ..... | ..... | 173660 | ..... | ..... | ..... | 4022 | ..... | |
| 2 | 9820 | ..... | ..... | 20186 | 94.7 | 61680 | ..... | 235340 | 35.5 | 2160 | ..... | 6182 | 53.7 | |
| 2½ | 13470 | ..... | ..... | 23836 | 130.0 | 73520 | ..... | 247180 | 42.3 | 1964 | ..... | 5986 | 48.8 | |
| 1 | 13016 | ..... | ..... | 23382 | 125.5 | 58280 | ..... | 231940 | 33.6 | 1550 | ..... | 5572 | 38.5 | |
| ..... | ..... | 1 | 2050 | 12416 | 19.8 | ..... | 23540 | 197200 | 13.6 | ..... | 230 | 4252 | 5.7 | |
| ..... | ..... | 2 | 3180 | 13546 | 30.7 | ..... | 69240 | 242900 | 39.9 | ..... | 1444 | 5466 | 35.9 | |
| ..... | ..... | 2 | 4144 | 14510 | 40.0 | ..... | 19380† | 193040† | 11.2† | ..... | 228 | 4250 | 5.7 | |
| ..... | ..... | 1 | 5416 | 15782 | 52.2 | ..... | 42060 | 215720 | 24.2 | ..... | 534 | 4556 | 13.3 | |
| ..... | ..... | 1 | 7466 | 17832 | 72.0 | ..... | 65920 | 239580 | 37.9 | ..... | 848 | 4870 | 21.1 | |
| 2½ | 5596 | 1 | 2632 | 18594 | 79.4 | | 56900 | 230560 | 32.8 | | 1596 | 5618 | 39.7 | |

creased to 340°F. by means of turbine steam bled to a feed water heater, the
ler units will be increased to 74700 pounds without changing any other data
200 lb. pressure and 620°F. bled per hour for this purpose.)

‡ If feed water temperature in No. 2, 3 and 4
heater the total steam generated per hour by
other data in the above table.
(8710 pounds of steam at 200 lb. pressure an

Steam Pressure at Superheater Outlets for all Studies 600 lb.
Steam Temperature at Superheater Outlets for all Studies 850°F.
Sytem of Draft — Closed Fireroom
Oil Fired—Six Oil Burners Per Boiler.
Total Weight Of 18500 B.T.U. Oil Burned Per Hour in all Studies.....5870 Lb.

| Percentage increase in total volume Percent | Temperature of feed water entering unit °F. | Temperature of air entering burners °F. | Temperature of gases entering uptakes °F. | Efficiency of boiler unit Percent | Total Steam generated by two boiler units pounds per hour actual | Total draft resistance thru boiler units (Room to uptake) inches of water | Total brake horse power required by fans | Percentage increase in horse power required by fans Percent | Approximate steam consumption of soot blowers per min. (one blowing) Pounds | Percentage increase in soot blower steam consumption Percent |
|---|---|---|---|---|---|---|---|---|---|---|
| ..... | 220* | 90 | 700 | 77.1 | 67400* | 1.79 | 8.8 | ..... | 3858 | ..... |
| 53.7 | 220‡ | 450 | 400 | 84.2 | 73520‡ | 4.83 | 23.7 | 169.4 | 4698 | 21.8 |
| 48.8 | 220‡ | 450 | 400 | 84.2 | 73520‡ | 4.28 | 21.0 | 138.8 | 6210 | 60.9 |
| 38.5 | 220‡ | 450 | 400 | 84.2 | 73520‡ | 3.72 | 18.3 | 108.0 | 7227 | 87.4 |
| 5.7 | 220 | 90 | 400 | 84.2 | 73520 | 2.59 | 12.7 | 44.4 | 4698 | 21.8 |
| 35.9 | 220 | 90 | 400 | 84.2 | 73520 | 2.46 | 12.1 | 37.5 | 4530 | 17.4 |
| 5.7 | 220 | 90 | 400 | 84.2 | 73520 | 2.61 | 12.8 | 45.5 | 5472 | 41.8 |
| 13.3 | 220 | 90 | 400 | 84.2 | 73520 | 1.91 | 9.4 | 6.82 | 3858 | 0 |
| 21.1 | 340 | 90 | 400 | 84.2 | 81600 | 2.63 | 12.9 | 46.6 | 4698 | 21.8 |
| 39.7 | 340 | 284 | 400 | 84.2 | 81600 | 3.70 | 18.1 | 105.7 | 5034 | 30.5 |

2, 3 and 4 studies is increased to 340°F. by means of turbine steam bled to a feed water
per hour by the two boiler units will be increased to 81600 pounds without changing any

pressure and 620°F. bled per hour for this purpose.)

(8) The air heater installation requires insulated ducts to convey the heated air from the heater to the fuel burners. An economizer requires no such bulky means to convey the heat it has picked up from the gases, a short length of feed pipe being all that is necessary to convey such heat from the economizer to the boiler drum.

Leaving generalities for a moment, it will be interesting to see what *definite* comparisons we get between the weight, cubic space occupied and essential engineering performance characteristics of some representative air heater and economizer studies. Such a comparison is shown in Table No. 1 which is based on the assumption that we have a ship of approximately 10,000 shaft horsepower driven by a turbine utilizing steam coming from the superheater outlets at a pressure of 600 pounds per square inch and a total temperature of 850 degrees F. To make the studies directly comparable from the air heater and economizer point of view, all of the ten studies shown in Table 1 are based on the assumption that the pressure parts, heating surfaces, weights, etc., of the two Express type (3 drum) boilers and superheaters with which the ship is fitted remain unchanged. The essential characteristics of these units is shown under Study No. 1 in Table 1, and are used as the basis for comparison of the other nine studies.

It is further assumed that the same weight of 18,500 B.t.u. oil is burned per hour under the two boilers (5870 pounds), releasing a total of 100,000 pounds of gas per hour, having an average $CO_2$ content of 13½ per cent for all eleven studies. With the particular boilers used in these studies, this gives a practically constant temperature of gases leaving them and entering the air heaters and economizers of 700 degrees F. The air heaters and economizers in turn have been so designed that the temperature of the gases leaving them and entering the uptakes is approximately 400 degrees F.

Except when bled steam is used from the turbine in a feed water heater, it is assumed that the feed water temperature to the boiler units is 220 degrees F. When the feed water temperature is raised to 340 degrees F. by bleeding, a reduction of approximately 1.5 per cent in total oil consumption may be expected for the same

shaft horsepower output of the turbine. As stated in the footnote at the bottom of Table No. 1, it is assumed that the increase in feed water temperature from 220 degrees F. to 340 degrees F. is obtained by bleeding 7975 pounds of steam per hour at 200 pounds per square inch pressure and 620 degrees F. total temperature, for the No. 1 study and 8710 pounds per hour for studies Nos. 2, 3, and 4.

If the temperature of the feed water entering the economizers of studies Nos. 5, 6, 7 and 8 were raised to 340 degrees F. by means of bled steam, there would be an increase in the uptake gas temperatures from these units of slightly over 70 degrees F., which would result in a corresponding reduction in the "boiler efficiency" of these units from 84.2 per cent to 82.5 per cent. This would almost exactly offset the saving of 1.5 per cent in oil consumption the use of the bled steam should give. This clearly indicates that there is nothing to be gained in heating the feed water going to an economizer above the "safe" temperature required to keep clear of the dew point of the acid vapor content of the gases, unless another "heat trap" such as an air heater is used beyond the economizer. The results to be anticipated from such an installation, using 340 degrees F. feed water to the economizer, are shown under study No. 10, in Table No. 1.

With this combination the benefits of both high stage turbine bleeding and suitably preheated air to the burners are accomplished without either the air heater or economizer being very large. Such installations are quite common in modern stationary power plants, but to date, as far as we know, only one such combination has ever been put in a ship. Possibly the average operator feels that such an installation will not only combine the good features of both air heaters and economizers, but their disadvantages as well.

In the particular ship under consideration it would be possible to maintain the desired efficiency of 84.2 per cent even with 340 degrees F. feed water to the economizers, if large enough economizers were used. This is shown by study No. 9 in Table No. 1, where two economizers similar to those shown in Figures 12 and 14 are used in series with a total heating surface of 7466 square feet. This may be compared to the economizer used in study No.

5 (similar to Figure No. 12) which gave the desired 84.2 per cent "boiler efficiency" with 2050 square feet of total economizer heating surface using an entering feed water temperature of 220 degrees F. The feed water leaving the economizer in study No 9 may at times approximate the steaming temperature, and accordingly the use of the integral type of economizer is a most desirable one in this case.

In connection with the studies shown in Table No. 1 it is to be remembered that the same boiler efficiency results could be obtained with a large number of modifications of each type of unit used in the respective studies. If less heating surface were desired for any particular installation, this can always be done with the realization that such reduction in heating surface and corresponding increase in heat transfer rate will invoke an increase in draft resistance and fan load. Conversely, if a reduction in fan load is desired for a given "boiler efficiency," this may always be accomplished by an increase in heating surface with a corresponding increase in weight and cubic space occupied. In preparing the various studies in Table No. 1 it was endeavored to maintain a reasonable balance between the heating surface, space, weight and fan load for the particular type of installation used in any one study.

Study No. 6 in Table No. 1 is of a 2-inch bare tube return bend independent type economizer as used extensively in power plants ashore. As may be noted, such a unit is in an unsatisfactory competitive position from a weight and space point of view aboard ship compared to the economizers used in the other studies shown.

In selecting the boilers and superheaters used as the "base" for all the studies in Table No. 1 the rate of operation (approximately, 0.7 pounds of oil per square feet of boiler surface) was set at a point which is between the usual Navy and Merchant Marine average procedures at the present time. This was done purposely, partly to avoid following either one of these too closely at the expense of the other, and partly to have relatively hot gases (700 degrees F.) entering the air heaters and economizers to bring out more emphatically the benefits that may be anticipated from the use of such units. Were a boiler installation to be made with

no thought of ever using air heaters or economizers, a slightly more efficient design of boiler could be employed by adding more surface, but with an operating pressure of 600 pounds per square inch at the superheater outlet (which will give a boiler water temperature of nearly 500 degrees F.), the gain that could feasibly be made in this way would not be very great.

It may be noted that in none of the air heater studies in Table No. 1 has any credit been given for improved combustion conditions due to the use of preheated air to the burners. Such credit will undoubtedly occur in actual service, but is impossible of exact evaluation on paper.

The efficiency values shown in Table No. 1 are based on the temperature, pressure and gas analysis given, using 18,500-B.t.u. oil having the following chemical composition:

| | *Per Cent.* |
|---|---|
| Carbon | 85.0 |
| Hydrogen | 11.4 |
| Sulphur | 1.5 |
| Oxygen | 1.0 |
| Nitrogen | 0.6 |
| Water | 0.5 |
| | 100.0 |

An assumed "Radiation and Unaccounted for" loss of 2.75 per cent as representative of average closed fireroom practice, has been used in the heat balances for obtaining the efficiencies by difference.

The weights of steam produced by the various studies contain in each case a small percentage of 600 pounds pressure and 538 degrees F. (50 degrees superheat) temperature steam to be used for auxiliary purposes in the ship.

From the preceding comparisons it would appear that an economizer installation has a number of points in its favor for ship installations, but it is to be kept in mind that the final analysis of this comparison cannot be made on paper, and is fundamentally dependent upon *service* experience, and the verdict of practical

operators with both systems. This verdict to date has clearly favored the air heaters as a far greater number of ships afloat today are fitted with air heaters than with economizers, and except for special cases, there seems to be no noticeable break in this trend. The general consensus of opinion among operators is that air heaters offer less of a hazard and less opportunity for interruption of schedule than do economizers, and if the ship is of such a type that air heaters can be satisfactorily worked into the space and weight requirements, the average operator would prefer them to economizers.

# CARBON–MOLYBDENUM CAST STEEL FOR STEAM SERVICE.

By HANS NAEGELI* and A. C. JONES.†

## INTRODUCTION.

The steel casting industry must be considered as an important factor in our great metal industry. There has been and probably always will be the need and demand for steel castings because of their fundamental nature and possibilities of designs which cannot be duplicated as economically by any other methods of manufacture. Unfortunately, steel castings have not always received the credit and recognition due them. The apparent retarded progress of the steel casting industry in the past, as compared to the accelerated rate of advancement made in other branches of the metal industry, has resulted in the unfortunate viewpoint of many that steel castings have been displaced by other types of fabrication. Such a viewpoint is entirely wrong and indicates a lack of appreciation of the vigorous forward advancements that the steel casting industry has made, and is making today. The purpose of this paper is to treat briefly some of these problems and advancements, particularly as related to the manufacture of one class of steel castings, namely, those required for high temperature, and high pressure steam service.

In the early days of the steel casting industry, users of the product experienced considerable difficulty in getting dependable castings. Most of this unreliability was due to insufficient knowledge of the factors governing the production of the castings. These include design, pattern construction, heading and gating, quality of metal, pouring technique, refractories, molding technique, cleaning, heat-treatment, welding and inspection. During the last few years, however, a systematic application of research

* Development Engineer, A. G. der Eisen und Stahlwerke vormals Georg Fischer, Schaffhausen, Switzerland.
† Research Engineer, Lebanon Steel Foundry, Lebanon, Pa.

has been made to these phases by progressive foundries so that steel castings from reputable producers are recognized as dependable units of important assemblies. Due to the necessary dependence on the human factor, perfection can be obtained no better on a steel casting than on a forging, rolled product, or welded assembly.

One great and important factor in the improvement of castings, especially with respect to their dependability, has been the closer cooperation between the designer and the foundry engineer. This has led to a better understanding of the limitations of castings with respect to certain designs which if employed would have to abrogate the laws of physical science to obtain good, sound castings. This matter will be referred to a little later on. The making of high-grade, dependable castings means more than just filling up a cavity in a refractory material with molten steel.

The engineer of today who is open minded enough to investigate the possibilities of steel castings, and at the same time forgetting the prejudices of the past, will find that they fit in nicely in the economical scheme of assembly in many fields of service.

## MOLDING PROBLEMS.

Practically all of the high-pressure casings of driving turbines are made of cast steel. Such a casting for modern steam service is one of the most difficult parts for a steel foundry to produce. Close cooperation between the turbine designer and the foundryman is absolutely necessary. (Figure 1 will familiarize the reader with molding terms that are to be used in the discussion to follow.)

In addition to the importance of design, there is the subject of the grade or type of metal to be employed, with consideration of the influence of the metal not only with respect to the service conditions, but also with relation to the obtaining of a high quality casting as such.

It is equally as important that the making of patterns and coreboxes be under the supervision of the foundry, as are the operations of molding, coremaking, melting, pouring, cleaning, welding, heat-treatment, and in some cases, rough machining.

A specific example will be used to illustrate the necessity of close cooperation between the designer and the foundryman, when

the former is preparing his designs for castings. Experience with castings of grey iron has developed a designing practice which has been satisfactory for that material, but requires considerable modification when applied to castings of steel. Take for instance a pipe 5 feet long, 2 feet in diameter, having a wall ½ inch in thickness, to each end of which is attached a flange. This can be produced in cast iron without any difficulty. When the designer for some reason or other desires a greater factor of safety without increasing the weight of the piece, he orders it of cast steel.

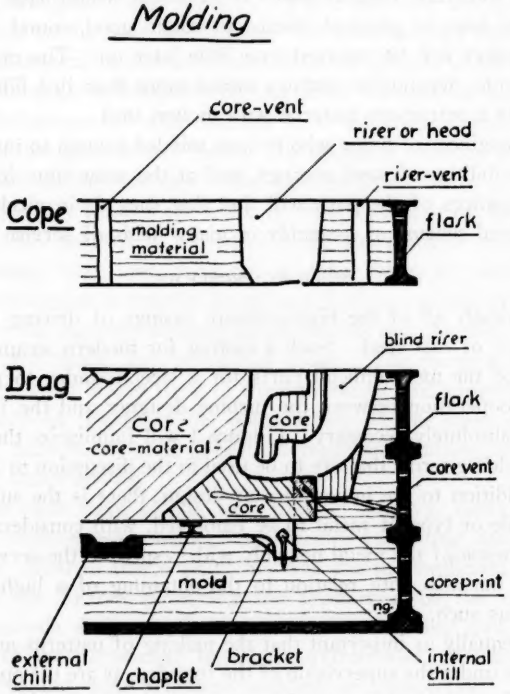



FIG. 1—ILLUSTRATING COMMON MOLDING TERMS.

If the steel foundryman is honest, he admits that it is impossible to make good castings of the above length and diameter, with only a thickness of ½ inch, because to do so requires a very collapsible mold and core to eliminate hot tears that will occur when this is poured as a steel casting.

The section of the contracting metal must be sufficiently great so that it will cause the mold and core to disintegrate and yield because of the strength of the metal section being greater than the resistance of the mold and the core. On the other hand, the core must not be weakened to the point that it is not strong enough to be satisfactorily handled; and both mold and core should withstand the pouring action of the metal. For these reasons, it is necessary that the wall section be at least ¾ inch, or preferably 1 inch.

In this special case, the steel foundryman might find it desirable to pour the piece with 1-inch section, and reduce the section to ½-inch by machining; however, this extra work and expense will rarely be justified on sections which require no finish machining.

Let us consider some of the greater difficulties encountered in pouring steel as compared to the conditions with grey iron:

(*a*) Steel is poured at temperatures between 2650 degrees F. and 3000 degrees F. This is between 400 degrees and 500 degrees higher temperature than that of grey iron. This higher temperature requires consideration of the most satisfactory molding materials that are available.

(*b*) The lineal contraction of cast steel is approximately 2 per cent, whereas that of grey iron is about 1 per cent. This means a greater hazard with respect to hot tears with steel castings of medium or great length, and considerable thought and care must be exercised not only on the designing table, but also in the manufacture of the molds and cores. These must be as collapsible as possible to allow the castings to contract as mentioned above. With grey iron castings there is no serious trouble with such cracks.

(*c*) The volume contraction (including a certain liquid shrinkage) with steel is about 9 per cent,* whereas with grey iron it is about 4 per cent. This means that greater attention must be paid to the feeding of cast steel sections so as to be certain that sufficient

* "Foundry Factors Affecting Steel Casting Design," by K. V. Wheeler. Transactions of American Foundrymen's Association, 1932.

molten metal is available at all cooling and contracting points. The risers have to be more numerous and also larger than with cast iron. Depending on the nature of the design, the weight of risers or heads may even exceed twice the weight of the casting proper.

(*d*) Molten steel is more viscous than cast iron. The latter fills the mold quickly and easily. Cast steel, however, must be well overheated, particularly for thin-wall castings. It is obvious that this injects additional problems involving different chemical and physical effects with respect to mold refractories. To further illustrate the comparison between steel and iron castings, the following points may be mentioned:

Melting equipment of a steel foundry is more complicated and expensive.

Removal of heads and gates from steel castings is more expensive, and also more difficult.

Since steel castings must be heat-treated, a well-equipped and modern treatment department is quite necessary.

All of these emphasize the necessity for more time in the case of steel, with respect to delivery.

Let us for a moment study the problems which confront the steel foundryman when he receives an order for a complicated steel casting, such as a turbine casing. (When hot tears are mentioned in the following paragraphs, cracks that occur due to restrained contraction are to be considered.) Figure 2 shows typical examples of hot tears and internal imperfections that will be discussed in succeeding paragraphs.

*Proportions of wall sections.* Great differences in sections often bring insurmountable difficulties with regard to tendency for hot tears. The position of these non-uniformities of section with respect to other conditions to be mentioned below must be kept in mind when studying the job. And as stated above, the wall thickness cannot be less than a certain minimum for a specific length or diameter (in the case of cylindrical sections). The designer of the turbine, to assure the obtaining of the highest quality of casting, should allow the foundryman permission to reinforce at those critical points.

*Distribution of masses.* The foundryman should be permitted, when it is practicable, to reinforce an intersection or parts of a

wall to allow feeding of the metal to the place requiring it, with a view to avoiding shrinkage cracks. Where such reinforcements are on the outside of the casting, the question arises as to whether they should be removed by expensive grinding or chipping, or allowed to remain as part of the finished casting. (Figure 3 illustrates these points.)

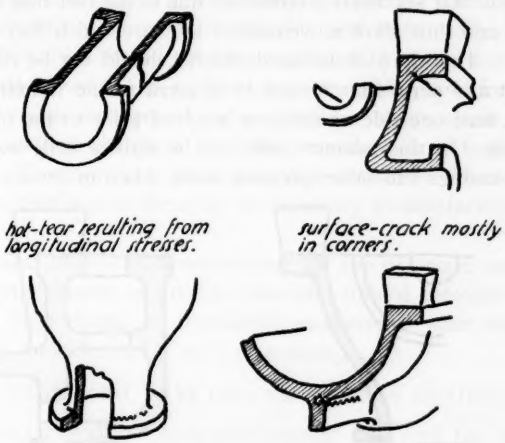



FIG. 2—TYPICAL HOT CRACKS.

*Use of chills.* Shall the foundryman use external or internal chills? Chills are a necessary tool for those castings having isolated sections which cannot be properly fed by risers or heads. Just as care must be exercised with other phases of steel foundry practice, so with chills a careful study should be made of their proposed application to any particular design. They must not be made too heavy or too light, but so that when the mold is filled their surfaces will be welded (in the case of internal chills) to the surrounding metal, and act as centers of solidification. In the case of external chills, they must be heavy enough so that they will not weld, but not so heavy that they will chill too greatly the section they are applied to, which may defeat their purpose. All chills must be carefully made, and the practice well controlled.

*Chaplets.* As in the case of chills, chaplets are imposed upon the foundryman by the nature of the design. Cores which are almost entirely surrounded by metal and of a design such that they cannot support themselves, must be held in position while the mold is being filled, by carefully designed chaplets. Just contrary to the effect desired with internal chills, the chaplets must not melt; otherwise their success is jeopardized due to the fact that they may weaken and thus allow movement of the core which they are controlling. Therefore an unfused chaplet should not be considered a defect and permission should be granted to the foundryman to weld at least one side of the area involved prior to the final heat-treatment. In this manner leaks can be satisfactorily avoided in turbine casings and other pressure work when in service.

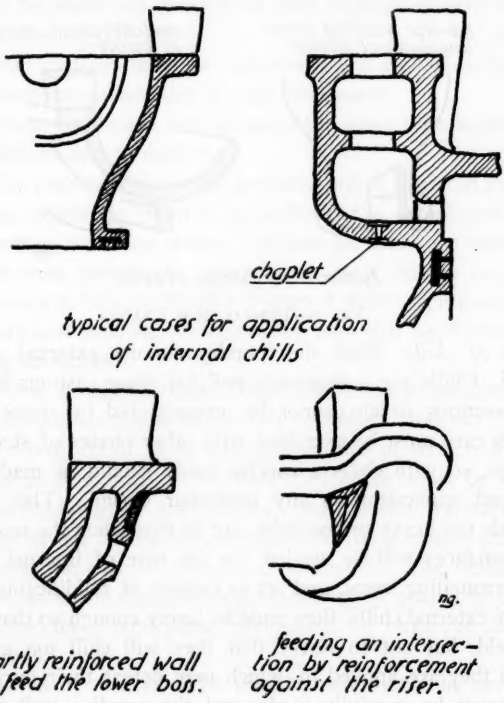

chaplet
typical cases for application of internal chills
partly reinforced wall to feed the lower boss.
feeding an intersection by reinforcement against the riser.

FIG. 3—APPLICATION OF CHILLS AND REINFORCEMENTS.

*Patterns and coreboxes.* Since the start of a successful casting (aside from the importance of design) is with satisfactory patterns and coreboxes, it is important that these be made carefully and properly checked. The motto, "A good pattern is the foundryman's best tool," is well worth remembering. Patterns and coreboxes should be split in such a manner that best results can be obtained in coring up the molds. The coreboxes, especially for a difficult section, should be of solid construction and open easily. Core-making difficulties should not be complicated by cheap and poorly constructed boxes. The turbine designer knows how important it is that inside surfaces of valve chambers, steam chests, steam passages and oil chambers be clean, smooth and as faultless as possible. Therefore care must also be exercised in the obtaining of good coreprints, as these are as necessary as satisfactory coreboxes.

The points mentioned above require the use of proper materials and the employment of artisans carefully trained through proper technical supervision, to thoroughly understand what they are doing and the reasons for such procedure.

## GRADE OF STEEL TO BE USED FOR PRESSURE CASTINGS.

Carbon cast steel has been satisfactorily employed for years in pressure designs with temperatures of 750 degrees F. or less. Within the limits of section and design possible for the foundryman to make in plain carbon steel, the stability or the creep resistance of the metal has been ample and quite satisfactory for the service intended. This is confirmed by the thousands of installations that have been made and which are and have proven satisfactory.

With the increase of steam pressures and temperatures specified by turbine designers, metals have been investigated with the purpose of finding a suitable material which without increasing sections, and therefore raising the weight, particularly for Naval applications, would result in equal stability at the higher temperature, to that of plain carbon steel at the former temperatures and pressures. To do this of course meant more than to simply make the nominal test of metals, such as tensile, bend, etc., at room temperatures. Even at the elevated temperatures of service these

short-time tests would not give a true picture of what the result would be after prolonged heating at these temperatures with respect to movement or creep of the metal. So it was necessary to actually measure the movement over a long period of time with constant and varying loads, and at the maximum temperature to be employed in service.

With the development of creep testing methods, progress has been made in determining which compositions were better than carbon steel, particularly at temperatures above 750 degrees F. This testing is being satisfactorily standardized in this country, so that results by different investigators will be comparable.

Recent comprehensive investigations carried on in America and abroad have been conducted to determine suitable compositions for service at elevated temperatures. It has been very definitely established that molybdenum is one of the most important elements introduced to improve the creep resistance. This has been very well brought out in recent literature and accumulated data. Just this past year a very good paper has been published by P. Grun.* Although his tests were conducted with accelerated creep testing methods, results of long time tests up to 1000 hours were found to be in general agreement. While this investigation was made on forged specimens, this should not affect the value of the comparison for us, inasmuch as it is generally conceded that cast steel has at least equal creep resistance to forged material of the same composition. Figure 4 shows curves that have been made from data developed by the late L. W. Spring, of the Crane Company.†

Although manganese, silicon, chromium and carbon produce improvement in creep characteristics, molybdenum has by far the greater influence. This is clearly demonstrated by a study of Figures 5, 6 and 7.

As has been described, a steam turbine casing is a very difficult piece to make even in plain carbon steel. To produce it of alloy steel increases the difficulties. Castability usually is less satisfactory than for carbon steel, because of the increase in the alloying

* "The Creep of Steel Depending on Alloying Elements and Heat-treatment," by P. Grun, Vereinigte Stahlwerke A. G. Dortmund.

† "Some Considerations and Tests for Cast Materials for High-temperature, High-pressure Service," by L. W. Spring, Chief Chemist and Metallurgist, Crane Co. "American Foundrymen's Association Transactions," October, 1931.

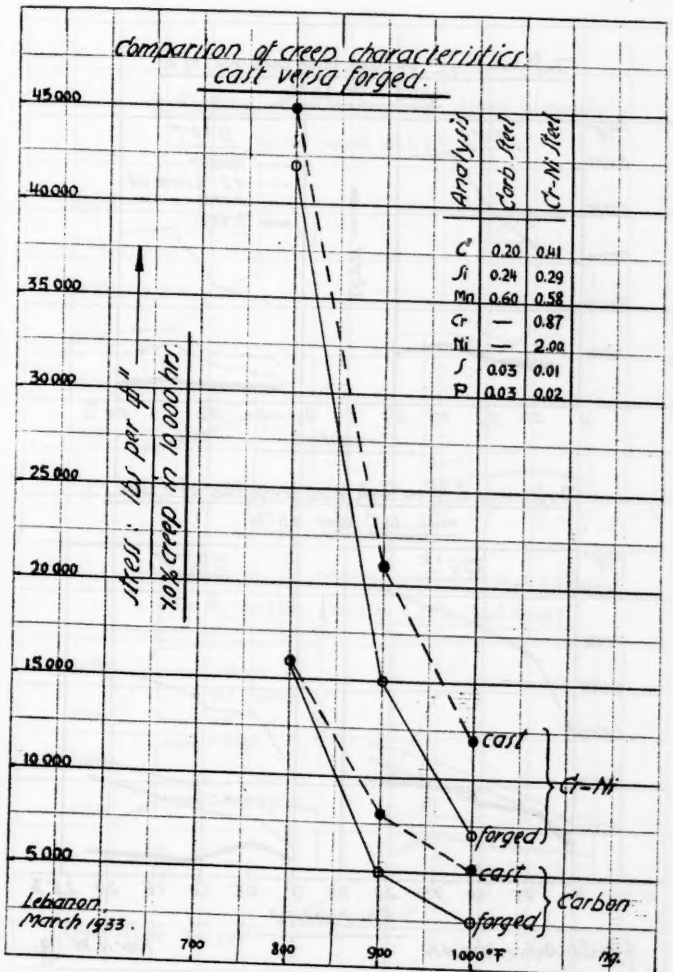



FIG. 4—COMPARISON OF CREEP CHARACTERISTICS OF CAST STEEL *vs.* FORGED STEEL (DEVELOPED FROM DATA REPORTED BY L. W. SPRING, OF CRANE CO.).

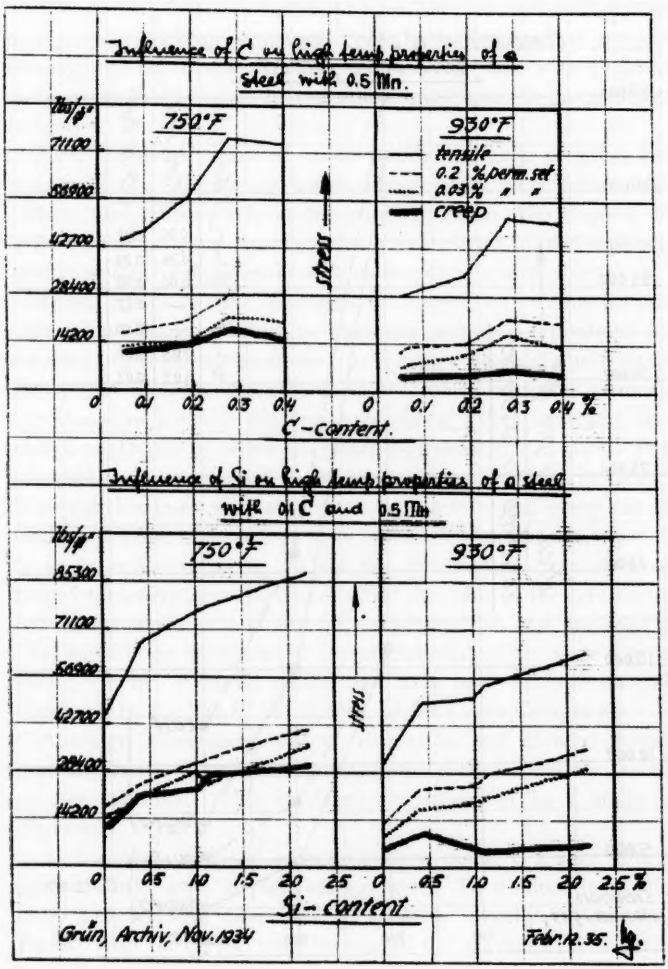



FIG. 5—INFLUENCE OF C. AND SI. ON CREEP PROPERTIES OF FORGED .50 MN. STEEL.

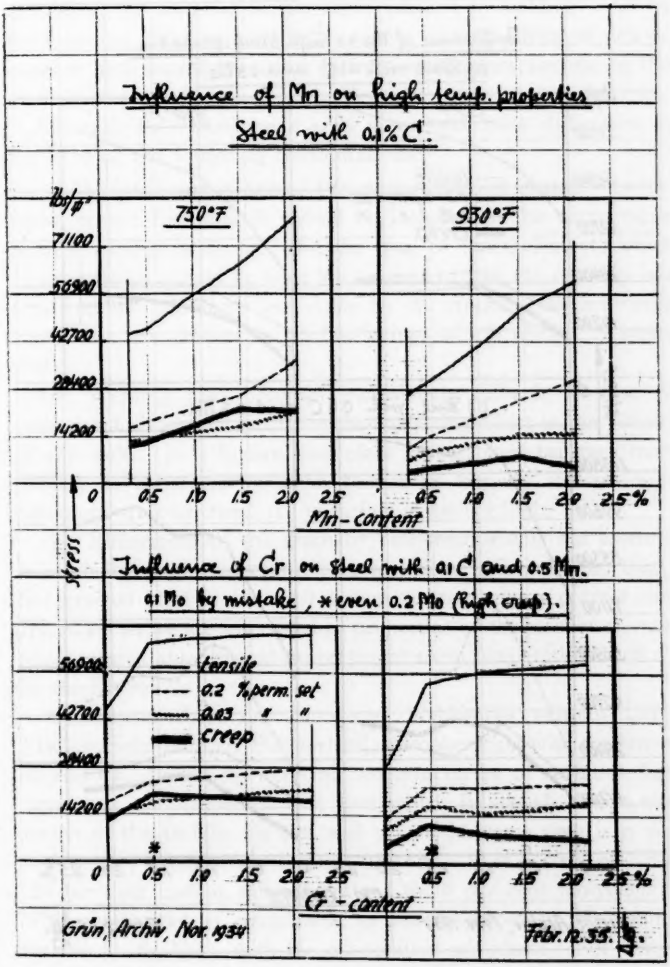



FIG. 6—INFLUENCE OF MN. AND CR. ON CREEP PROPERTIES OF FORGED .10 CARBON STEEL.

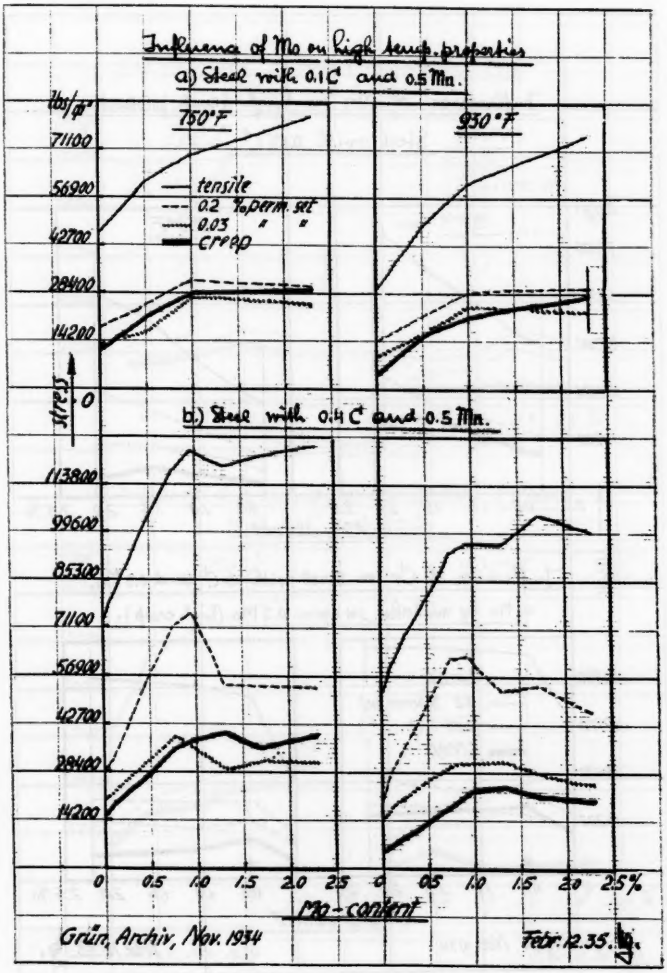



FIG. 7—INFLUENCE OF MO. ON CREEP PROPERTIES OF FORGED STEELS WITH .10 C. AND .40 C.

elements. And because of the more complicated heat-treatment necessary, the material becomes less adapted to welding. All of these factors point toward greater losses, to say nothing of delays, expense and sometimes a not entirely satisfactory casting in the plant of the purchaser.

Naturally the foundryman tries to prevent these difficulties in the light of the following considerations:

(*a*) Molybdenum is one of the most important elements to improve creep; therefore it should be included in the composition because of this tendency. But the total of those elements which form carbides should be kept low so as to make the castings less sensitive and therefore less liable to the troubles characterizing steels that are subject to air-hardening, which results in stress cracks.

(*b*) Welding also becomes increasingly difficult because of stresses which are set up due to the hardening effect in the vicinity of the weld. It is known that plain carbon steel becomes more difficult to satisfactorily weld, so far as keeping stresses to a minimum are concerned, if the carbon is unduly high.

(*c*) Refinement of the grain by heat-treatment is not essential in steels for high-temperature service, since it is indicated that a fine-grained steel is not as resistant to creep as a coarser one. Inasmuch as we are interested in properties of the steel at elevated temperatures, the physical properties at room temperature need not be emphasized.

Aktiengesellschaft der Eisen-und Stahlwerke vormals Georg Fischer, Schaffhausen, Switzerland, in cooperation with the Brown Boveri Co., Baden, Switzerland, manufacturers of turbines, have developed a molybdenum cast steel which fulfills all the requirements of the turbine builder, and yet at the same time is a very satisfactory composition for the foundry. It is a steel of .18 to .25 per cent carbon, alloyed with .4 to .5 per cent molybdenum. This composition is comparable to that developed in this country by the U. S. Navy with the cooperation of others. For several years, nearly all of the turbine casings, valves and other pressure castings for high temperature steam service have been manufactured of this material in the Fischer plant, with practically no

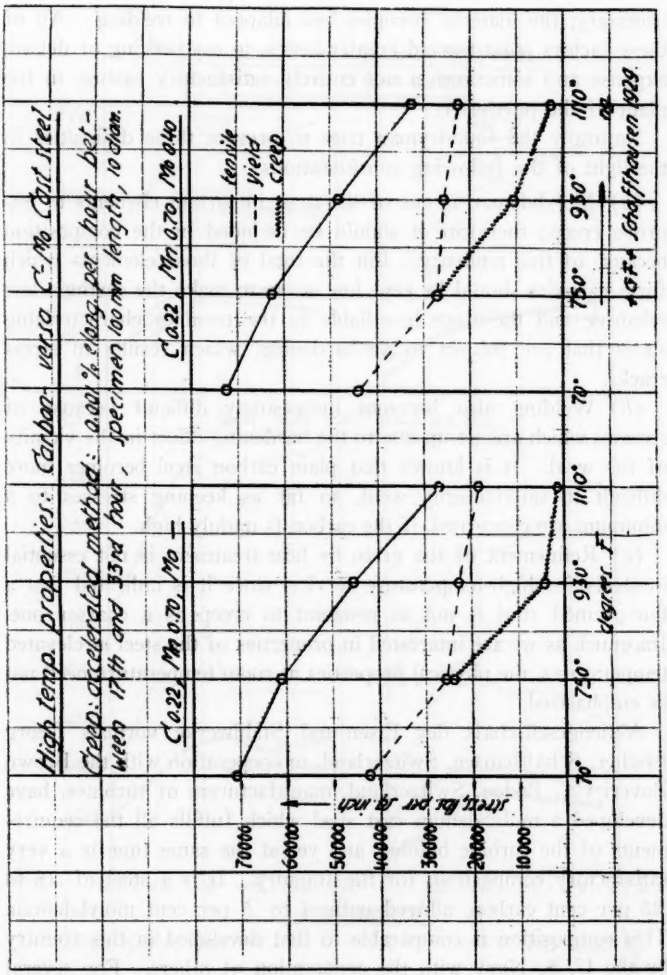



FIG. 8—HIGH TEMPERATURE PROPERTIES OF CARBON VS. CARBON MOLYBDENUM CAST STEELS DEVELOPED BY A. G. EISEN UND STAHLWERKE VORMALS GEORG FISCHER, WITH COOPERATION OF BROWN BOVERI CO.

greater difficulty than with those made of plain carbon steel. Some of these castings are illustrated in Figures 14, 15 and 16.

Excellent creep properties are obtained in castings of this composition, and at temperatures between 750 degrees and 900 degrees F. are more than double those of plain carbon steel at the same temperatures. (See Figure 8.) This comparison was made as the result of employing a test bar of 10 millimeters diameter in determining the stress which produced a rate of flow of 0.001 per cent per hour between the 17th and 33rd hours of the duration of the test at the particular temperature.

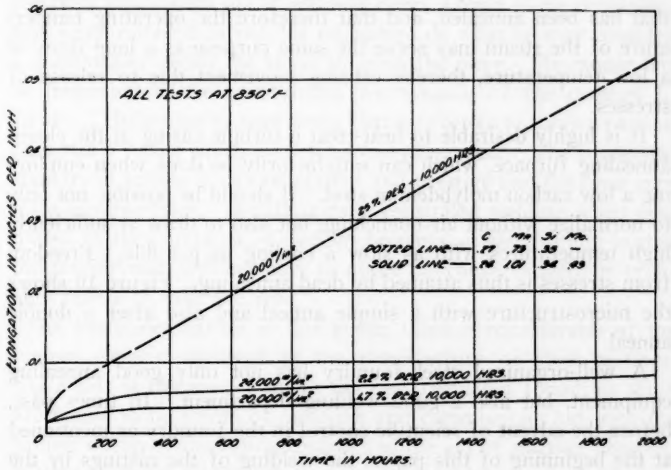



FIG. 9—CREEP COMPARISON BETWEEN CARBON CAST STEEL AND CARBON MOLYBDENUM CAST STEEL AT 850 DEGREES F. TESTS MADE BY BETHLEHEM STEEL CO.

Long-time creep tests that have been made in this country confirm the above comparison. Figure 9 shows the curves of carbon and molybdenum cast steels for the temperature of 850 degrees F.

This graphically illustrates the superior creep resistance of the carbon-molybdenum steel with tests conducted according to the recently standardized method of determining creep. The creep tests illustrated in Figure 9 were conducted at the creep testing laboratory of the Bethlehem Steel Company, Bethlehem, Pa.

## HEAT-TREATING, WELDING AND INSPECTION.

As previously mentioned, steels have been developed employing several alloying elements which have excellent physical properties and particularly good creep resistance. These properties are obtained usually by a more or less complicated heat-treatment of the castings, whereby air-quenching often plays a big role. It is obvious that a steam turbine casing is not a casting that should be air-quenched. Dangerous stresses are developed as the result of uneven distribution of mass. In addition to this, it must be realized that an air-quenched casting may not be as stable as one that has been annealed, and that therefore the operating temperature of the steam may serve the same purpose as a long draw at a low temperature, thereby causing movement due to release of stresses.

It is highly desirable to heat-treat a turbine casing in the closed annealing furnace, which can satisfactorily be done when employing a low carbon molybdenum steel. It should be possible not only to normalize without air-quenching, but also to draw at sufficiently high temperatures with as slow a cooling as possible. Freedom from stresses is thus attained by dead annealing. Figure 10 shows the microstructure with a simple anneal and also after a double anneal.

A well-organized steel foundry has not only good annealing equipment, but also a good welding department. In times past, before the advent of scientific control in the foundry as mentioned at the beginning of this paper, the welding of the castings by the foundry was in the estimation of the purchaser a necessary evil and an admission or probable evidence of very poor foundry practice. This is not denied. It is well realized that welding has sometimes been abused, but a contributing factor to this was the imposition of almost impossible designs forced upon the foundryman because of the lack of a mutual understanding between him and the designer, as mentioned before.

The art of welding has advanced remarkably during the past few years, and progressive steel foundries have done considerable investigational work to so develop their welding technique and train welders that they would be able to repair defects in the

castings they produced, with the aim of having the repaired casting as good as one that needed no repair. The welding room is one of the most important departments of a well-equipped and modern foundry, and is subject to metallurgical control, just as in the case of the heat-treating department.

The steel foundryman is conscientious in manufacturing his castings; he strives for the best results. But experience has taught him that some defects are liable to be found in a complicated casting, and particularly if only one or two castings are to be made from a pattern with which no previous experience has been gained. He feels no concern about welding them, except in an occasional case when rather than risk his reputation on what he may consider a questionable repair, he elects to scrap the piece. He cannot but be interested in the satisfactory performance of the castings in service. He knows by experience that it is better to scrap a casting than risk a repair which may not prove permanent. The successful foundry is jealous of its reputation and prestige and does not care to jeopardize them. Metallurgically controlled welding when permitted by the purchaser of castings becomes an asset to him in that the foundryman will not have to quote too conservatively or probably refuse to take the job.

As mentioned earlier in this paper, there is considerable of the human element involved in the manufacture of steel castings. Since this is the case, even in the best regulated foundries there are bound to be errors of omission and commission; but with the proper set-up of inspection control and the aid of such an excellent tool as modern welding, the consumer should have no fear of an inferior product because it has been welded. This is especially true when it is appreciated that the castings are heat-treated after welding, as a standard practice.

Inasmuch as welding must be considered a regular procedure in the manufacture and application of castings, the material must demonstrate satisfactory welding properties. This the carbon-molybdenum steel has done as will be shown in succeeding paragraphs. It is obvious that any unsound areas must be completely eliminated so that the weld can be built up on good dense metal. The electric arc can be used to good advantage to thoroughly explore suspected areas, with the assurance that a satisfactory job

has been done. A graphite electrode of 1 inch diameter, with a dynamo setting of 100 volts on a no-load basis, and which furnishes from 400 to 600 ampères, is used. Working in this manner, a good V opening with clean flanks, which are necessary in efficient welding, is obtained.

As previously mentioned, steel with several carbide forming elements is less suited for welding than a simpler steel, which is not too sensitive to air-hardening. Even a plain molybdenum steel with 1 per cent of this element tends toward excessive air-hardening which may result in hard spots and stress cracks in and about the weld. A cast steel of .25 carbon, .90 manganese and .50 molybdenum can be electrically welded with a heavy flux-coated molybdenum electrode of similar composition, without this danger.

This molybdenum alloy welds very satisfactorily. Figure 11 illustrates tension and bend tests that have been made, employing a heavy flux-coated electrode. These tests were made with 1¼-inch cast plates grooved to a 75-degree V, and test bars cut transversely in the case of 1 and 2, and turned to the standard .505-inch specimen and pulled, following an anneal at 1250 degrees F. It is interesting to note the remarkable physical properties obtained in specimen No. 3, which is made of all-weld metal. The physical properties of the specimens illustrated in Figure 11 are as follows:

*No. 1.*

| | |
|---|---|
| Proof stress | 49,000 pounds per square inch |
| Yield point | 51,100 pounds per square inch |
| Tensile strength | 65,500 pounds per square inch |
| Elongation | 21.9 per cent in 2 inches |
| Reduction of area | 66.1 per cent |

*No. 2.*

| | |
|---|---|
| Proof stress | 48,000 pounds per square inch |
| Yield point | 50,550 pounds per square inch |
| Tensile strength | 69,000 pounds per square inch |
| Elongation | 23.0 per cent in 2 inches |
| Reduction of area | 66.8 per cent |

*No. 3 (All-Weld Metal).*

| | |
|---|---|
| Proof stress | 47,000 pounds per square inch |
| Yield point | 48,000 pounds per square inch |
| Tensile strength | 62,800 pounds per square inch |
| Elongation | 32.1 per cent in 2 inches |
| Reduction of area | 67.6 per cent |

Bend specimen—Elongation in outer fibers of the weld metal—40 per cent.

The composition of the parent metal was:

| | |
|---|---|
| Carbon | .23 |
| Silicon | .47 |
| Manganese | .74 |
| Molybdenum | .48 |

The chemical analysis of the deposited metal is:

| | |
|---|---|
| Carbon | .10 |
| Molybdenum | .49 |
| Silicon | .11 |
| Manganese | .56 |
| Sulphur | .003 |
| Phosphorus | .024 |

Even though final heat-treatment is desired and recommended, tests that have been made indicate that it is possible in the case of an emergency to weld a molybdenum steel casting in service without any subsequent heat-treatment, when carefully done. This may prove to be of particular advantage for emergency repairs aboard ship. Results obtained in such tests are shown below:

PHYSICAL PROPERTIES OF WELDED SPECIMENS WITHOUT SUBSEQUENT HEAT-TREATMENT.

The specimens, values for which are given below, were sections from a cast plate of the following analysis:

| | |
|---|---|
| Carbon | .23 |
| Silicon | .47 |
| Manganese | .74 |
| Molybdenum | .48 |

This material is the same base metal as employed in the welds illustrated in Figure 11 and referred to previously in this paper. The single V notch was employed.

| | *Yield Point (Pounds)* | *Ultimate Tensile Strength (Pounds)* | *Elongation (Per Cent)* | *Reduction of Area (Per Cent)* |
|---|---|---|---|---|
| Bar No. 1 | 38,660 | 68,410 | 17.2 | 39.1 |
| Bar No. 2 | 36,490 | 69,350 | 14.8 | 30.4 |

Bend specimen No. 1—Elongation in the outer fibers of bent section—35.1 per cent.

Bend specimen No. 2—Elongation in the outer fibers of bent section—38.8 per cent.

A photograph of the specimens reported above is shown in Figure 12. (Specimens were bent until first crack occurred.)

To determine the maximum hardening effect of the molybdenum steel in welding, without subsequent heat-treatment, and also to compare it with the manganese-molybdenum (an alternate composition which is permitted in the recent tentative specification by the Navy for turbine castings and the like), specimens of both steels in the heat-treated condition were grooved and one bead of weld laid across the faces. These faces were then carefully ground down, and hardness determinations made across the weld, with both the Rockwell B and Rockwell C indentors. These values were converted to Brinell and are plotted in Figure 13. The maximum hardness obtained with the molybdenum steel was equivalent to 390 Brinell, whereas the manganese-molybdenum steel had a maximum hardness of 495 Brinell. These tests were made solely to demonstrate the maximum hardening effect without benefit of a subsequent heat-treatment. They should not be confused with results obtained after proper stress relieving treatment as shown in previous tabulation.

If the purchaser of quality castings is acquainted with the facts herein described, it should be possible in the future to discuss prices and deliveries on more agreeable terms, due to a better understanding of the conditions necessary for the production of such castings. Inspectors should feel safe in granting permission

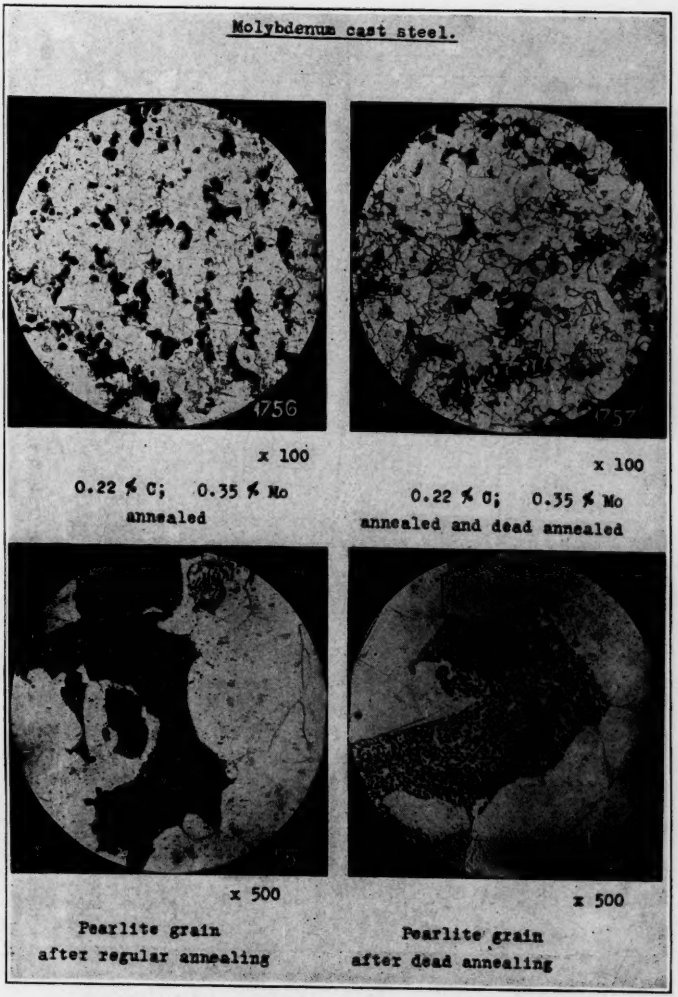



FIG. 10—MICROSTRUCTURES OF CARBON-MOLYBDENUM CAST STEEL.

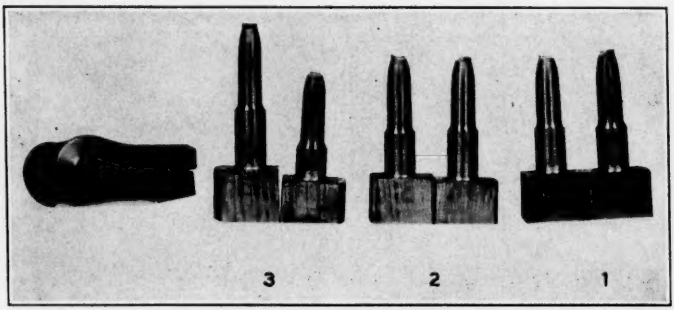



FIG. 11—PHOTOGRAPH OF WELDED TENSILE AND BEND SPECIMENS AFTER TEST. STRESS RELIEVED AT 1250 DEGREES F. AFTER WELDING.

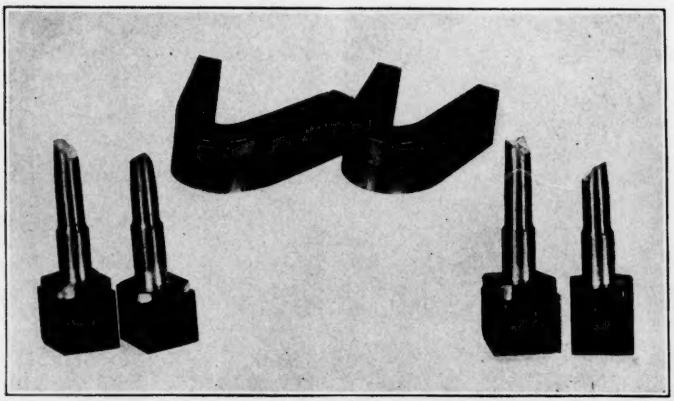


FIG. 12—PHOTOGRAPH OF WELDED TENSILE AND BEND SPECIMENS AFTER TEST. NO SUBSEQUENT HEAT-TREATMENT AFTER WELDING.

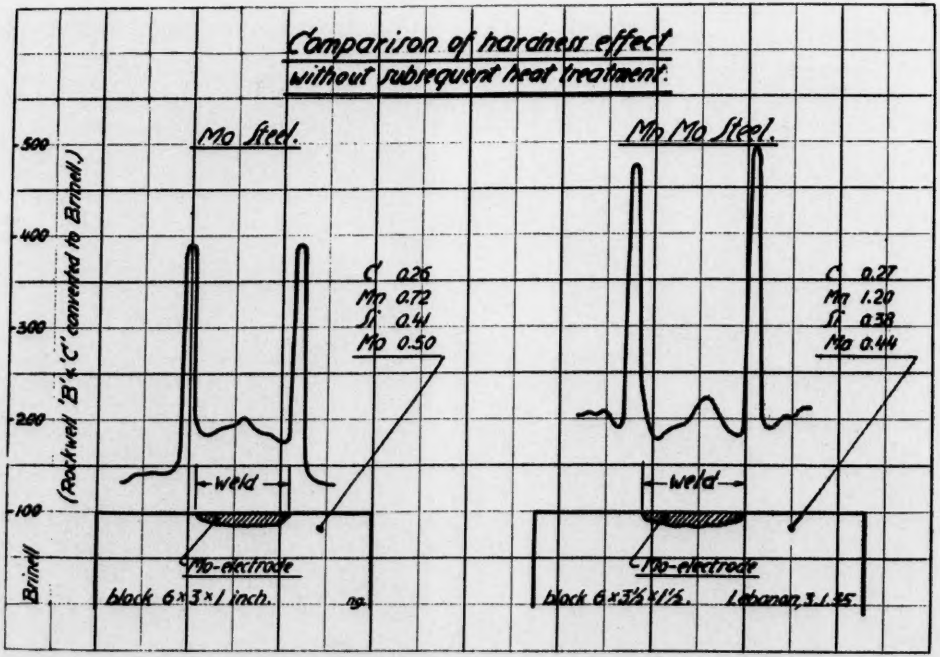



FIG. 13—COMPARISON OF WELD HARDNESS EFFECT WITH NO SUBSEQUENT HEAT-TREATMENT—C-MO. CAST STEEL *vs.* MN-MO CAST STEEL.

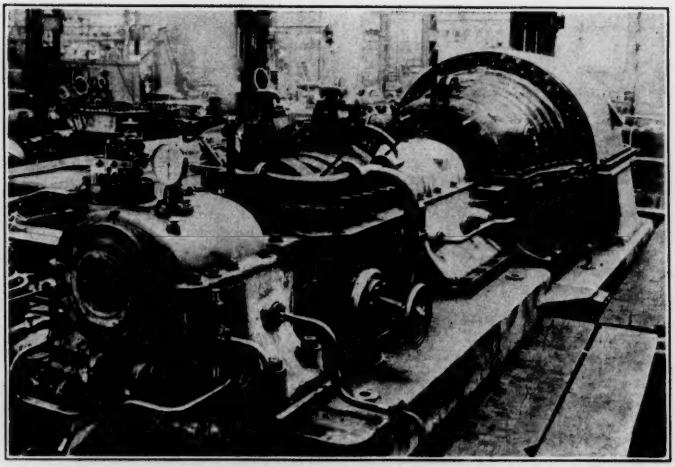


FIG. 14—HIGH PRESSURE CASING (C-MO. STEEL) AND MEDIUM PRESSURE CASING (CARBON STEEL) MADE BY GEO. FISCHER FOUNDRY. (HIGH PRESSURE CASING TOTAL WEIGHT 4.5 TONS.) (STEAM PRESSURE 995 POUNDS, TEMPERATURE 930 DEGREES F.)

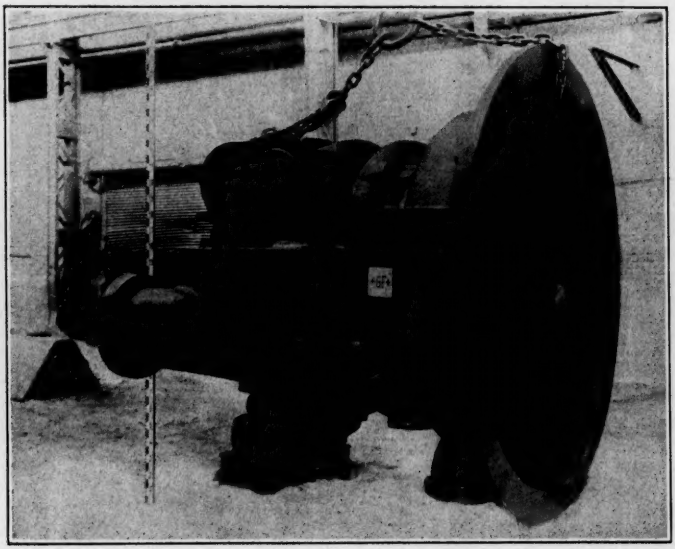


FIG. 15—HIGH PRESSURE CASING (C-MO. STEEL) MADE BY GEO. FISCHER FOUNDRY. TOTAL WEIGHT, 17.5 TONS.

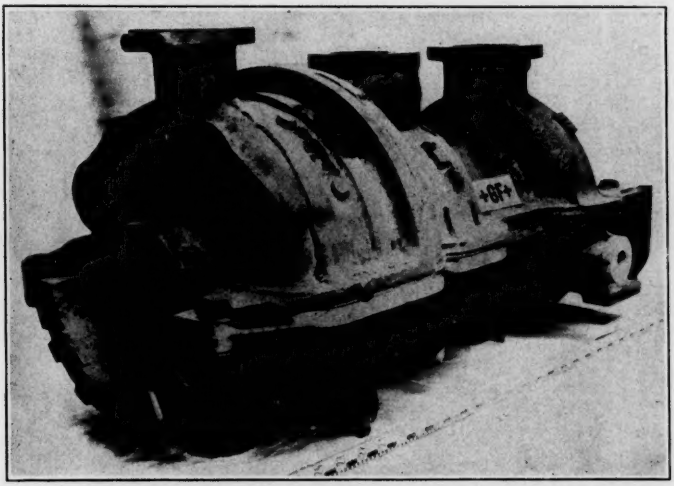


FIG. 16—HIGH PRESSURE CASING (C-MO. STEEL) MADE BY GEO. FISCHER. TOTAL WEIGHT OF 3 PARTS, 5 TONS.

FIG. 17—WHEEL CASE FOR STEAM SERVICE.

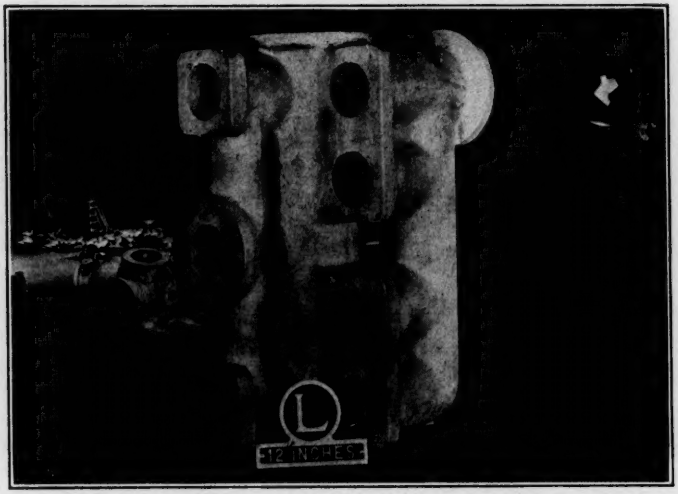



FIG. 18—LIQUID PUMP CYLINDER.

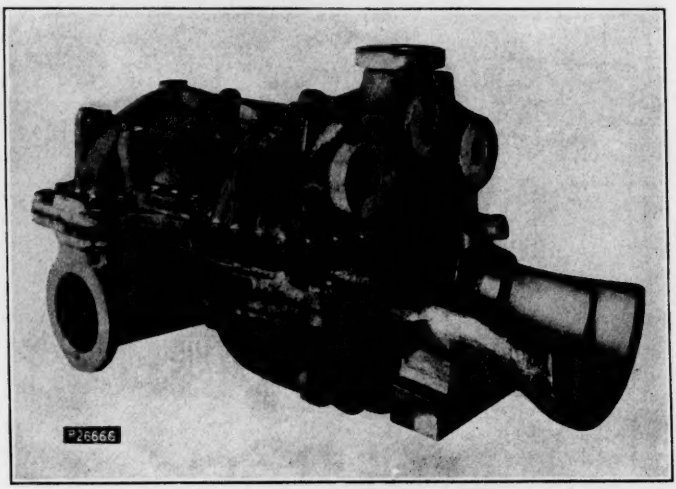



FIG. 19—UPPER AND LOWER CYLINDER CASTINGS FOR HIGH PRESSURE TURBINES.

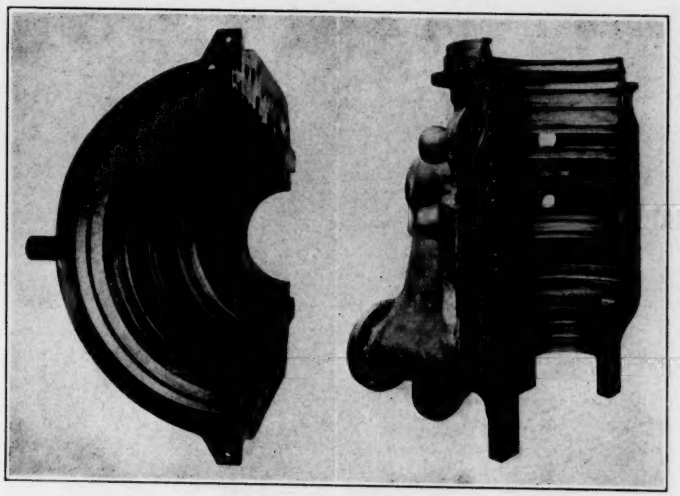


FIG. 20—HIGH PRESSURE TURBINE CASING.

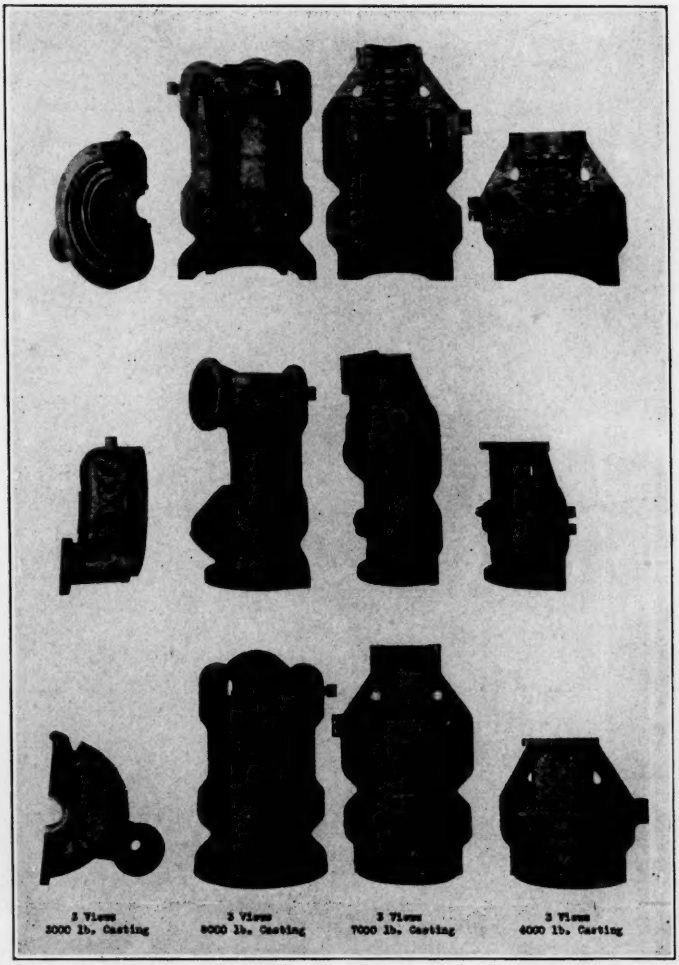



FIG. 21—HIGH PRESSURE TURBINE CASINGS, BETHLEHEM STEEL CO.

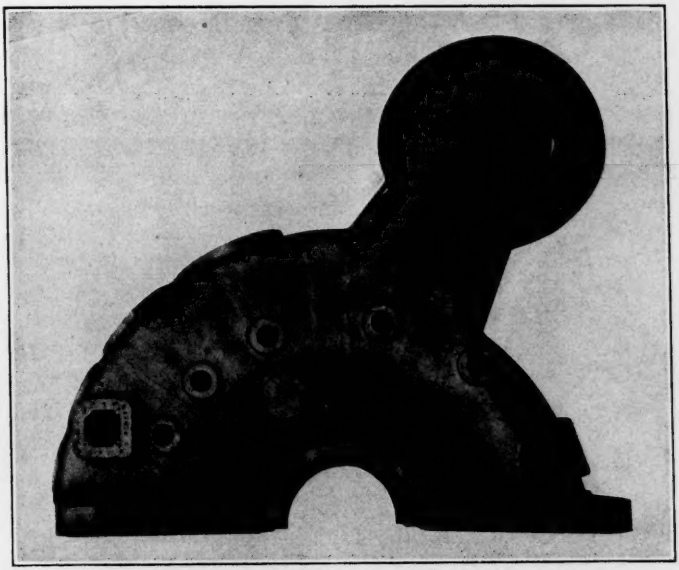


FIG. 22—FORWARD END (4000 POUND CASTING) HIGH PRESSURE TURBINE.

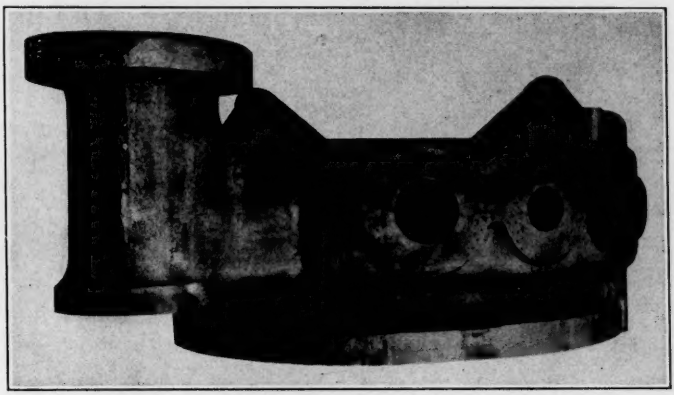


FIG. 23—SIDE VIEW (4000 POUND CASTING) HIGH PRESSURE TURBINE.

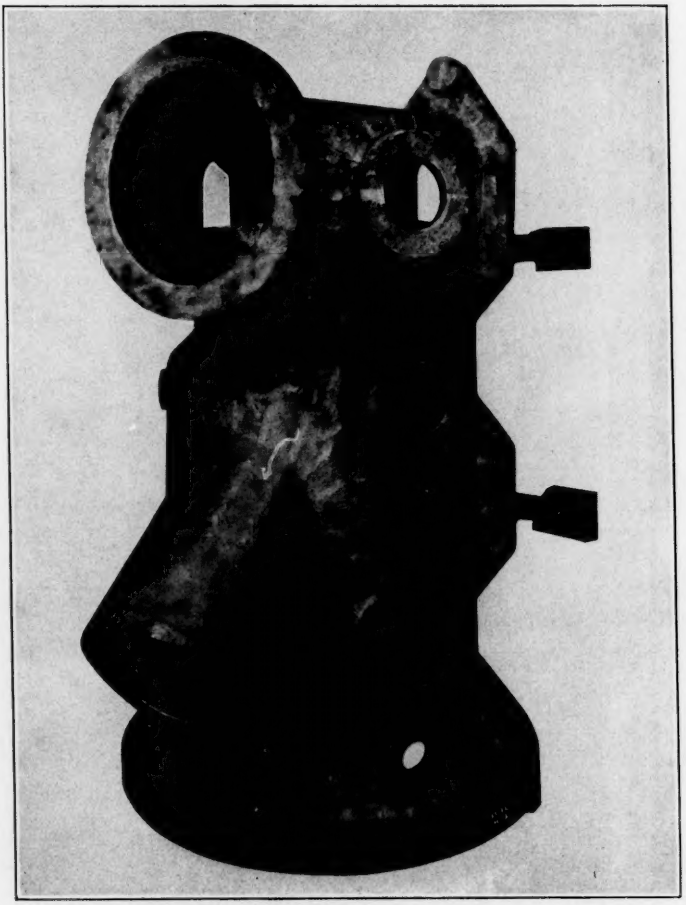


Fig. 24—Upper Aft (8500 Pound Casting) High Pressure Turbine.

to make normal welds as requested by the conscientious foundry, which at all times is ready to prove its ability in this respect. Through such close cooperation, success is bound to result.

In Figures 17 to 24 are illustrated pressure castings of carbon steel made by the Bethlehem Steel Company and the Lebanon Steel Foundry, which can be satisfactorily duplicated in the carbon molybdenum alloy.

It should be appreciated that the foundryman must not be pressed too greatly by the limitations of price and weight, as doing this may affect the quality of the turbine casing involved. The turbine is one of the most important parts of the vessel, yet involves only a small percentage of the total weight and invested capital of the ship.

This paper has attempted to discuss the problems of the steel foundry when producing steel castings for pressure service, and particularly casings for steam turbines, and how it can be eased by whole-hearted cooperation between consumer and manufacturer. The use of a certain molybdenum steel has been recommended after satisfactory physical properties and weldability have been demonstrated.

The authors wish to acknowledge the kind assistance of Mr. P. E. McKinney, of the Bethlehem Steel Co., for suggestions offered in the preparation of this paper and for the creep data submitted.

# THE MARINER'S COMPASS.

By Captain John M. L. Gorett, M.S.R., C.C.A.

It is worthy of notice and in keeping with the purpose of what I am about to write that of the many factors which have played a dominant part in the forming of our civilization, not any other one has contributed so much nor so important constructive material as the SHIP.

The greatest legends of mankind have been enacted mostly upon the sea; and seamen in the early days, even as now, were and are our most beloved heroes: Danao, Ulysses, Vasco de Gama, Magellan, Captain Cook, Nelson, Captain Slocum. For it is at sea as nowhere else that man's ingenuity, dignity and steadfastness are bred and tested.

I also hold that man's mental and spiritual progress has always followed in the wake of his mastery of the blue water of the sea, and that had not the physical venture come first as a pointing beacon of what could be achieved by trying, the social advancements may have remained but dreams of the suffering multitudes oppressed and unfortunate.

In the very beginning of history we find the boatman sailing in daytime only and never losing sight of the land; for although in possession of a craft quite strong enough to brave a measure of open water, he dared not trust himself to the uncertainty of the weather as his only source of direction lay in the visibility of astral bodies. Man's desire to see and know what was beyond the horizon, his ineradicable longing for what he did not possess sharpened his mind, and in the days of Homer we find the outward-bounder well stocked with live birds so that whenever the lay of the land was wanted, a bird was released, and, by noting its direction of flight (always toward the nearest land) a bearing of some sort would be obtained. The drift of clouds associated with the quality of the wind conveyed useful information; for if the wind was cold the clouds would come from the North, and if it rained, from the East and so forth.

Although the Mediterranean, the Red Sea and the Persian Gulf were the entire world in those days, and voyages were short by choice, we find record of long ones which were taken by compulsion and, somtimes even accomplished without better direction indicators than a dozen live crows, the sun and the following star table, which, of course, held good only for certain and limited latitudes:

| | |
|---|---|
| North | Polaris. |
| N. E. | The point on the horizon where the constellation of the Ram arose. |
| E. N. E. | The point on the horizon where the constellation of Arcturus arose. |
| E. | Midway point. |
| E. S. E. | The rising of the sword of Orion. |
| S. E. | The rising of the constellation of Scorpio. |
| S. S. E. | The rising of Canopus. |
| S. | The Pole opposite Polaris. |

Stirring days those were when our earth was flat and demons and sea-serpents were very real and waiting for the adventurer whichever way he might turn.

It is quite erroneous for a large number of writers to hold that the Chinese made use of anything like a compass at an earlier date than the Europeans did. During my investigation of the subject I have found Chinese documents, the writers of which in various epochs described their vessels with great care and a wealth of details as to the hull, the masts, and the sails, the sleeping and cooking arrangements, as well as references as to how those often large ships were handled; but I find no allusion whatever to the compass or to anything which may have served as an instrument of direction, besides birds, clouds, the sun and various star tables. My conclusion on the subject is rendered doubly secure by the fact that those very Chinese writers from whom I have drawn my information, often refer to the extraordinary power of the magnet. While obviously aware of its attractive property, they remained quite ignorant of its other, and, by far more important characteristic, of pointing to the North.

I also dismiss any possibilities as to the Arabians having had any knowledge of the compass although they were well acquainted with the magnet, as were also the Grecians, who used it in their Academies, and I find Plato speaking of it with some humor as of its being used by jealous husbands to test wifely virtue.

Marco Polo, in his narratives states that on the Arabian ships he had voyaged on, there was no "Bozzolo" (Venetian for compass). He passes on to say that the vessel had four masts, only one rudder, seventy cabins for the merchants, and was navigated by the Astrologer who, sitting high and all alone with the astrolabe in his hands, and holding great thoughts, gives orders. Knowing what an accurate reporter Marco Polo was, I cannot help inferring that it would have been impossible for such a remarkable instrument as the compass, no matter in what form, to have escaped his notice; besides, the Astrologer would not have sat high, probably at the mast-head had there been an instrument of direction on the ship.

It is in a volume dealing with the Art of Ship Handling, written in Latin, title and author unknown, as the title page is missing, but which I place in the third century A. D., that I find the description of what may have been a compass. I give it as I found it: "Take a number of small iron bars (needles) and paint them with a mixture of cinabro and orpimento well powdered and mixed with the blood of the crest of a rooster. Heat them well, and, after the Astrologer has carried them next to his skin for a period of a full lunation, lay them on straws floating on the water and they will point South."

Surely this is magic and not physics. Still I cannot rid myself of the thought that, perhaps, it was a bundle of magnetic needles, and, that it really was Physics camouflaged by magic, and the humbug of cinabro and the crest of a rooster were employed merely to hide the true nature of the needles.

Whatever it may have been, it was not adopted, for one finds nowhere any further reference to the magic process and ships continued to be navigated by the astrologer, who, sitting high with the astrolabe in his hands and great thoughts in his head, gave orders. He was probably the original look-out man who, being aware of the earth's sphericity, knew how to hold a good job by keeping his knowledge to himself.

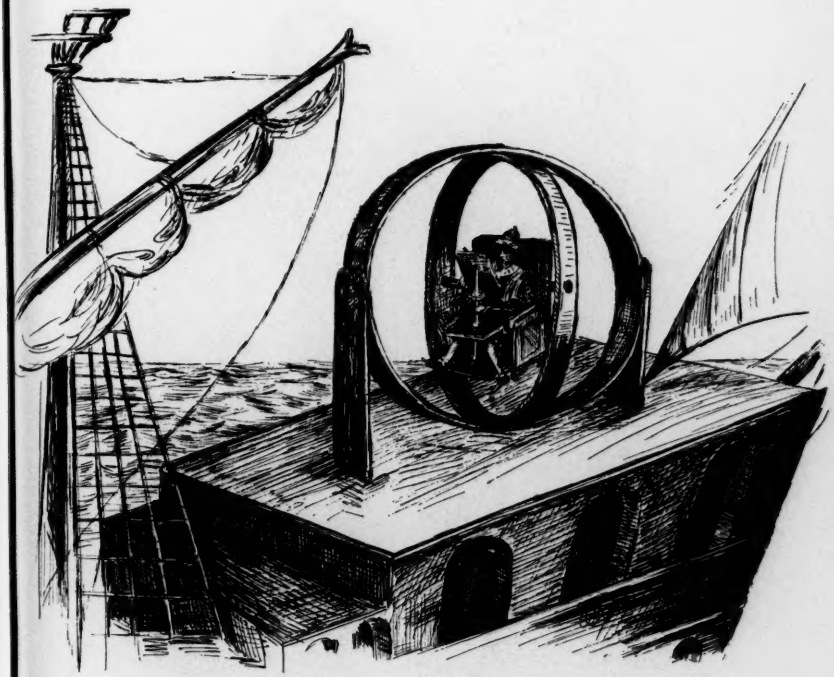


FIGURE 1.—THE ASTROLOGER SITTING HIGH AND ALL ALONE WITH GREAT THOUGHTS IN HIS HEAD GIVES ORDERS. THE INSTRUMENT HE IS SITTING IN WAS KNOWN AS THE "ORIENTATUS" (THE FINDER OF THE WAY), A. D. 1200.

FIGURE 2.—ASTROLOGER NAVIGATOR OF THE 1500 CENTURY MEASURING THE ALTITUDE OF A CELESTIAL BODY WITH THE ASTROLABE, THE PRECURSOR OF THE SEXTANT.

FIGURE 3.—MARINIERE ON NORMAN SHIP, A. D. 1200 CIRCA.

It is during the reign of Ludovico IX and precisely with a certain Brunetto Latini a Florentine to whom Dante referred as "Il Maestro mio" that in his poem entitled "Tresor," and written in France in 1248 circa I find mention of Norman ships being sailed with the aid of an instrument called the Mariniere, and described as follows: "In a tub of water placed in the center of the ship there floats the Mariniere, which is a round piece of cork with a thin hollow shaft filled with lodestone inserted through its center so that it lies parallel to the plane of the water, and the quill of a goose sealed at both ends, also inserted through the cork at right angles to the one filled with lodestone; over this there lays a bird's skin with the Fleur de Lys upon it, and even as our august King is our constant guide on the land, so does the Fleur de Lys upon the Mariniere guide the mariner by constantly pointing to Boreas (North) no matter how the ship may go."

To this very day, seven centuries later, practically every ship's compass card has a Fleur de Lys impressed upon its North point.

Cardinal Jacques de Vitry in 1250 circa assures us that the Marinette (as it became known later) gave splendid service and we may well believe it, although Variation had not yet been spoken of.

The advent of the Marinette gave large impetus to navigation in Northern waters, although it was not adopted for many years to come by the navigators "East of Suez." Voyages, however, became more frequent and speedier, and fifty years after the advent of the Marinette we find merchants cashing notes from the Indus to Normandy, and ordering goods with the time of delivery indicated for the first time in history. The astrologer was called down from aloft and installed in a small cabin erected on deck to house the Marinette and called the "Habitatus"* which in time became the Bittacle and is now-a-days known as the Binnacle; *i.e.* a housing arrangement for the compass.

It is odd, but not surprising that no mention is made anywhere of the man who discovered the North-seeking property of the magnetic needle, nor of the one who devised so clever an adaptation of this property to the requirement of navigation. Those were

* *Habitatus*, Latin for habitation or dwelling.

not the days of rugged individualism (for a consideration) and the inventor may have felt sufficiently rewarded by the knowledge that greater glory would attach to God and King for his discovery.

Useful as the Marinette turned out to be, it had the serious drawback of being thrown against the side of its container whenever the ship rolled, and in a high sea had to be taken out of it altogether to keep it from utter destruction.

To overcome this defect, Messere Flavio Gioia, an Amalfitan, devoted his knowledge of Physics and Mechanics, and in the year 1295, circa, he evolved the first compass the world had ever known really worthy of the name. In place of the wooden tub filled with water in which the Marinette had floated heretofore, he employed a huge copper bowl which, when the ship's head is swinging in Azimuth* by generating electro-magnetic induction, the current of which will be in such direction as will tend to bring the needle to rest sooner than if the tub was made of wood is a decided advantage in damping the oscillations of the compass card. In the center of the inside of the bottom of his copper bowl he secured a slender shaft on the vertical, upon the well pointed upper end of which he balanced a compass card, showing not only the Fleur de Lys on its North point, but the other cardinal points as well, and by covering it with a glass top blown at Murano, evolved a compass which in principle, if not in details was the same as the ones we use at present. This he called the Bussola,† for as the card proved to be somewhat sluggish on account of what must have been an enormous weight upon the pointed pivot with resulting retarding frictional resistance, it had to be tapped from time to time to keep it from sticking upon the pivot.

I would fain impress my reader that the facts herein stated are the result of most painstaking investigation extending over twenty years of time, and not mere hearsay.

Very little gain, however was reaped by Elavio Gioia for his adaptation of the magnetic needle, and I rather think that of the millions who have staked their lives upon the compass, or won fortunes and everlasting fame by the aid of it, not a handful has

---

* *Azimuth*, from the Arabic for direction.

† *Bussola*, from the Italian "bussare," to tap.

ever given thanks to the Amalfitan who labored not for himself but for the future brotherhood of mankind.

In Sandres, a small town of the province of Algarves near Cape St. Vincent in Portugal, Don Enrico, the Fifteenth Infante, in the year 1480 established the first Nautical Academy for the purpose of furthering the Art of Navigation. Learned men, Philosophers and Astrologers, shipwrights and pilots came from the Mediterranean and northern France to confer with each other, Hydrographic charts were composed, the great Gnomone which stands to this day was constructed and seventeen years after its inception the Academy had accomplished so much that on the eighteenth of July, 1497, at high noon, Vasco de Gama in command of four vessels sailed forth to the discovery of new lands, equipped with compasses, charts and astrolabes of a perfection never before achieved. King Don Emmanuel was present at the sailing ceremony and marveled much at the compasses which in general principle and application, if not in details were very much the same as the ones we use today, invented in Normandy, adapted in Italy and perfected in Portugal. Man's advance in most fields of endeavor has ever been by leaps and bounds, and the art of compass making remained at a standstill for a long time inasmuch as three centuries after Columbus, equipped with a not too erroneous chart of the east coast of North America, and piloted by a Guernsey sailor, had landed in San Salvador, we find the British Admiralty advocating the use of long magnetic needles in the construction of the compass card in the erroneous belief that the larger the needles, the greater must be the sensitiveness of the card.

William Thompson (born in 1824—died 1907) later to be known as Lord Kelvin for his contributions to the science of Physics in its many branches, in the year 1878 revolutionized the practice of compass making and compass adjusting by proving that the shorter the needles the more satisfactory both the compass and its adjustment would be, and astonished the world by reducing the weight of the compass card from 1600 grains to 190 grains, thereby minimizing momentum due to frictional force at the pivot and achieving the most sensitive compass ever as yet devised.

It was a holosteric (free of liquid) compass; and, after most satisfactory tests, its use became well nigh universal.

In 1906 Mr. Bernard of the Magnetic Observatory of Greenwich patented his spherical compass, departing from the conventional by having a hemispherical glass top, which, forming with the bowl a spherical container for the card, reduced the disturbing effects of rolling, and pitching that cause an unsteady card. In spite of its obvious advantages over the flat top compass, it remained a comparatively unknown instrument until 1930, when, in a much improved form, we find it to be quite a success in the U. S. A. where it has been adopted by small boats as well as ocean liners with satisfaction being expressed by its many users.

In 1920, or thereabout, Henry Hughes and Son of London evolved the "Dead Beat" compass, which considered from any angle is indeed difficult, if not impossible to beat.

The diameter of the card has been much reduced, and its weight is the least that could be compatible with the existence of matter, for here we have precisely no more than 115 grains of weight on the pivot. The wide space existent between the sides of the bowl and the edge of the compass card prevents the same from being affected by any eddies which may exist in the liquid due to the motions of the ship. The magnets, only two and one-half inches long for the ten inches compass, are made of cobalt steel, which is a great improvement in itself. A special system of damping filaments has been introduced which, coupled with the very ingenious method of suspending the compass in the binnacle by means of plungers and shock absorbing material, renders this compass so immune to the disturbing effects of vibration, rolling, pitching or turning, as to be of an almost uncanny immobility.

Before purchasing a compass for a certain vessel, two quantities should be borne in mind, as well as a number of qualities, *viz.:* The period of roll of the ship and the period of the compass. The former is the number of seconds of time that elapse between two successive rolls of the ship, and is rather uncertain, varying for the same vessel according to the state of the sea and the metacentric height of the ship, although we may ascertain the maximum. The latter is the number of seconds employed by the compass card to return to its original position when deflected forcibly, as by a magnet, a certain number of degrees, say 40, and is a very

definite quantity ruled by many factors such as the weight of the card, the intensity of the magnetic force of the needles in it, the damping property of the material used in its construction and the size of the compass. Without entering into a technical discussion of this very complex branch of Physics, it will be obvious to anyone that if the two periods should happen to coincide, they would in a seaway, combine to create a wildly swinging card which would make the steering of courses an utter impossibility. This inconvenience can sometimes be overcome by altering one's course a couple of points or so, if permissible, and by reducing or increasing the speed of the ship.

I have had recourse to these expedients a number of times with entire success both under canvas and with power on small as well as large vessels.

An intelligent and honest expert (I mean *expert,* not would-be expert) should be consulted in this matter and be made to give a precise statement on the subject, and not uncertain and equivocal phrases which can only be used to hide his ignorance, his desire to pass off something his firm specializes in, or what he may call a bargain. I can think of very few more pathetic sights than to watch someone walk into a shop asking for "A compass for my boat" and to see him walk out of it with one and the assurance that what he has purchased is being used by so-and-so-and-so, without a word having been spoken as to the peculiarities of the ship he is going *to try to use it on.*

As to where best installed, I can only say that Necessity, Aesthetics and Fancy should call on Science to aid them in choosing a place for the compass on your ship.

Many things can and often do happen to a compass in the course of time that you may never be aware of, but which nevertheless will cause the loss of a race or the making of landfalls a few miles from where you expected to make it, and, quite regardless of the nautical knowledge of owner or sailing master, compasses should be inspected both as to mechanical defects and deviation every year, by an accredited and competent (which is not the same thing by far) Compass Adjuster.

It is however regrettable that our laws which compel a plumber to possess a certificate of competency before he is allowed to repair

our kitchen sink, will permit anybody to tamper with a compass while posing as an *Adjuster* with results that are often regrettable and, have at times been known to lead to disaster.

Do not place a loud-speaker or engine room tools nor harpoons or other hardware within ten feet of the compass. Do not carry a knife or keys when near it.

Do not let the sun beat down upon it, as it is not made of stone, but of very delicate parts.

It is not my purpose to give here a treatise on magnetism but merely to suggest that a compass be accorded the care which your eyes receive, for the compass is indeed the mariner's eye; it sees in the dark, and leads us all in all sorts of weather to high adventure, romance and independence, which we may never have known but for a Norman, about whom all is known is that he was a Norman, an Amalfitan whose very resting place is as much a matter of conjecture as anything can be, and a Scotchman, who, by refusing to accept the practice of his contemporary as final, made it possible for the present navigator to place his vessel within her own length from a distance of eight hundred and even more miles, regardless of fair weather or foul.

I wish to acknowledge my indebtedness to Captain Boris Knack for his illustrations in pen and ink which were done from memory, the originals being preserved in the Museum of Venice, and in the National Museum of Warsaw.

# THE MANUFACTURE OF MARINE PROPELLERS.

By COMMANDER L. M. ATKINS* (CC), U. S. N.

In the multitude of things which comprise the whole of the design of any ship, there is probably no element which, more than the propeller, intrigues the interest of the designer. This comparatively minor unit of a ship's structure is the final determining factor in the problem of getting the most of the propulsion dollar on the job of actually moving the ship. The job of applying the well known standards of the ancient screw principle to a system in which all the elements have a continually changing and an infinitely different relation with each other, is one which stimulates admiration because any progress at all has been made.

One wonders whether there is merit in the search for efficiency by chasing thousandths of inches from one place to another or by insistence upon niceties in the contour, pitch, rake, and area of blades. However, the research has brought results and the chase goes on. Much has been published about propeller design, but relatively little about propeller manufacture. The man in the design room and the man in the shop are seemingly in two different worlds, yet it is rare that praise or recrimination echoes between them because of the demonstrated performance of a particular design. To the designer belongs the spoils.

Nevertheless, all along the line, before the propeller exhibits its own skill, there are introduced little touches of skill of artisans which may modify some design element from which much is expected. Of course, the shops have no objective but to reproduce perfectly the design. In so intricate a matter, success of the shop is almost as marvelous as that of the designer. The technique of shop practices in producing propellers is largely empirical. It is affected by the minds of men, the type of equipment they have at hand and, no doubt, by the climate they live in. In the mechanical processes there may be varying degrees of argument as to whether

* The Production Officer, Industrial Department, Navy Yard, Philadelphia, Pa.

one procedure is better and another worse, but there is no calculable answer to whether one procedure is right and another wrong. In the hope of gratifying to some extent the curiosity of the uninformed and of adding a little to the meager store of information on the subject for the benefit of those interested, these notes on shop practices at the Navy Yard, Philadelphia, are commended to the generous consideration of their readers.

The assignment of propeller manufacture to the Navy Yard, Philadelphia, seems largely to have grown up from a force of habit. It appears to have begun to gravitate there, at a time when the founders of the metal composition, everywhere, were having their troubles with compounding the mix and setting the molds, properly to control the losses from non-homogeneous material, strength deficiencies and unsound castings. A former Master Molder at Philadelphia seemed to have particularly consistent luck in these respects. General practice has become fairly satisfactory in most places where the making of propellers is done. However, there seems some ground for the suspicion that in spite of experience and precaution, there is an occasional failure, though perhaps not always chargeable to the foundry.

The hope of the manufacturer that an accurate reproduction may be made of the design, looms largest in the pattern shop. More so than with most products involving castings, the patternmaker must be guided from the beginning by the effect his handiwork will have upon the succeeding operations. The multiplication of a linear dimension by a constant shrinkage factor serves the purpose of a satisfactory product in many types of work, but propellers are temperamental in this respect. Shrinkage works in so many different directions that provision must be made at the beginning to offset the possibility of errors in pitch, blade droop, cracks, and porosity which cannot be rectified in the machine shop. What provisions are made by the patternmaker will depend, for example, upon how the pattern is placed in the mold to suit the most satisfactory foundry practice where the casting is made. Unless the same foundry practice is followed for every casting made from a given pattern, the pattern will not produce a propeller correct to design. Unless the foundry procedure intended when making the pattern is known to different founders who may use that pattern,

trouble is sure to follow, even to the point of question whether the pattern has been correctly made.

In the practice of the pattern shop, Navy Yard, Philadelphia, for the patterns of propellers having a constant pitch, a so-called propeller machine is used. A level layout board is provided, large enough to lay down full size, the projected and developed contour of the blade, one-half of the hub and about seven sections of blade thickness laid radially from hub to tip, using an appropriate shrinkage rule. A template is made to serve as a guide in developing the correct pitch. On a full circle, the radius of which is about two feet greater than that of the actual propeller, standards are set upright. Against these, the pitch template is set so as to determine the location of a rail secured to the uprights. This rail forms a guide rest for the swinging pitchometer arm of the machine; see Plate A.

For beginning the manufacture of the pattern, a hollow stock from which the hub will later be cut is set over the center post of the machine. The hub stock is formed of sections about 2 inches thick and wide enough to form a half hub plus the formation of the fillet joining the hub to the blades. To this hub are successively fastened wood blocks of suitable thickness (about 2¼ inches) and of sufficient width so that, when set at the approximate pitch angle, their faces can be scribed with the exact cross section area of the blade at that point.

For development of the blade face a sliding guide is attached to the arm of the machine. The arm is set through adjustments provided to conform to the rake angle of the blade. The sliding guide carries a fixed steel pointer. As the arm swings in azimuth around the center post with the outer end of the arm in contact with the guide rail, the pointer, placed in contact with the face of the wood block last secured to the hub projections, necessarily scribes a line corresponding to the pitch face of the blade; see Plate B.

For development of the back of the blades, points are projected from the surface of the layout board to the pitch face as scribed on each section. The thicknesses at that section are then laid out normal to the pitch face. The points thus established form a fair curve which is scribed through them to give the outline of the back of the blade.

Thus the blade outline is formed on one side of each wood block section making up the pattern. The section is removed and the outline of the blade section scribed is transferred to the opposite face of the block so that successively each section can be quickly sawed to shape on a band saw. It is then replaced and secured by screws and glue to the next section previously built up. These operations are repeated until all sections are assembled. The face of the blade is checked by straight edge and the pattern is then planed down to true form. The finished pattern is provided with a heavy batten bolted across its face to prevent warping; see Plates C and D.

The procedure for the pattern of a propeller having variable pitch is largely the same as above, except that the pitchometer arm cannot be used. It is customary, therefore, in laying out the blade on the level layout board to increase the number of radial blade sections to about ten. The points for both the pitch face and the back of the blade are projected from the board to the pattern section at the point.

Except where the size of the propeller is small enough to make the molding procedure simpler, one blade and the contiguous hub section is sufficient for building the propeller mold. Of course, when propellers are to be built in pairs to opposite hands, a separate pattern is required for right and for left hand wheels. The blade patterns for matching pairs of wheels are built up at the same time with the same set up of the propeller machine, the patterns being set on opposite sides of the machine spindle. This procedure insures remarkably close similarity of the dimensions of the two patterns.

When received in the foundry for molding, a lifting plate of sufficient size and strength is leveled and centered over a spindle seat. A spindle is then placed on the seat, trued up and fastened at the top. A sweep is secured to the spindle, at a sufficient height to enable the molder to sweep the hub base and piers. These piers are necessary for two reasons: First, to enable the molder to strike off his center lines, and, second, as a solid foundation on which to support the stools which hold the blade pattern level. The core print and hub tests are then bedded in. The pattern is then placed in a position on the center line, leveled and firmly secured. Special

PLATE A.—MACHINE FOR MANUFACTURE OF PROPELLER PATTERNS.

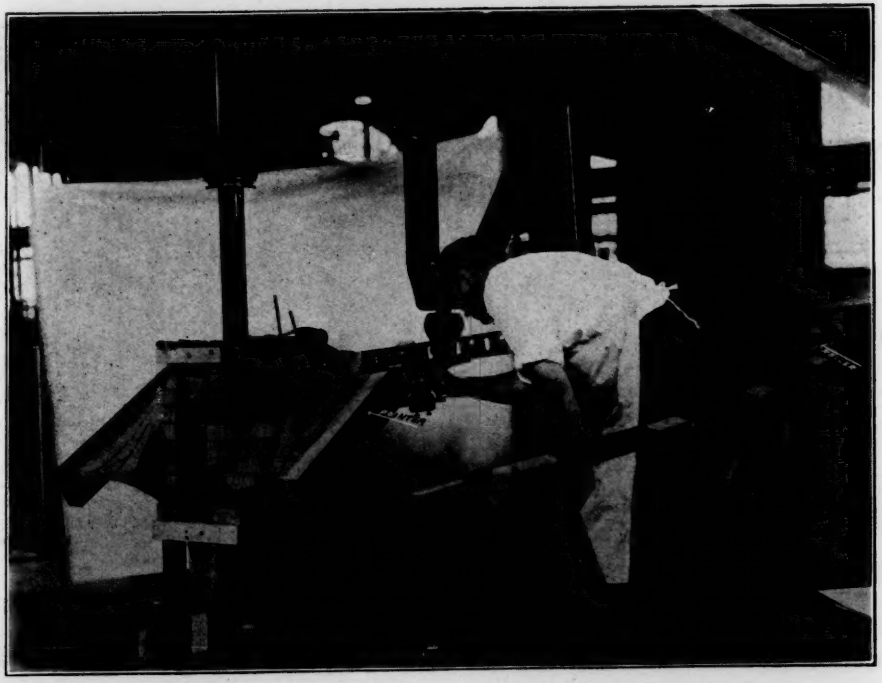


PLATE B.—METHOD OF LAYING OUT PITCH FACE CONTOUR ON BLADE SECTION.

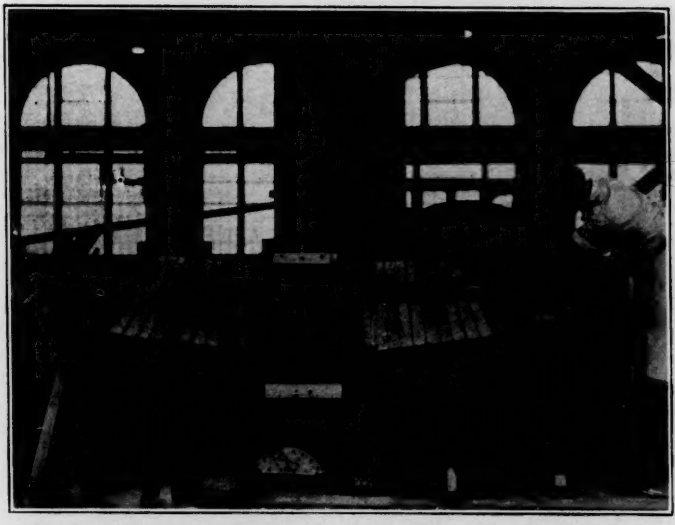


PLATE C.—ASSEMBLED ROUGH PATTERN SHOWING CHECKING OF FACE.

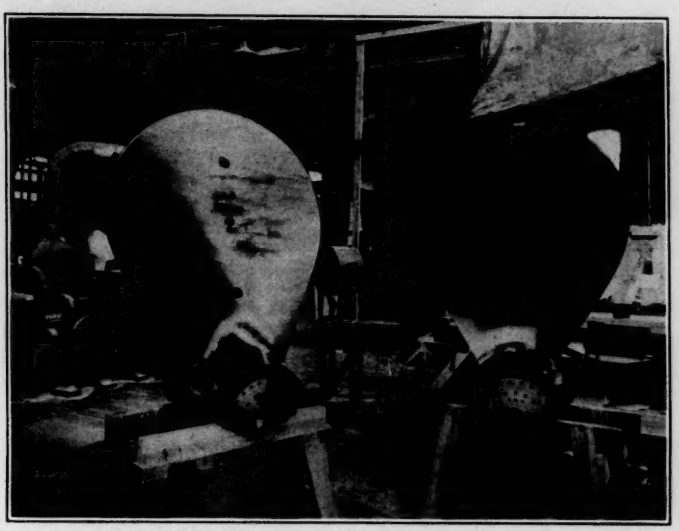


PLATE D.—FINISHED PROPELLER BLADE PATTERNS.

PLATE B.—METHOD OF LAYING OUT PITCH FACE CONTOUR ON

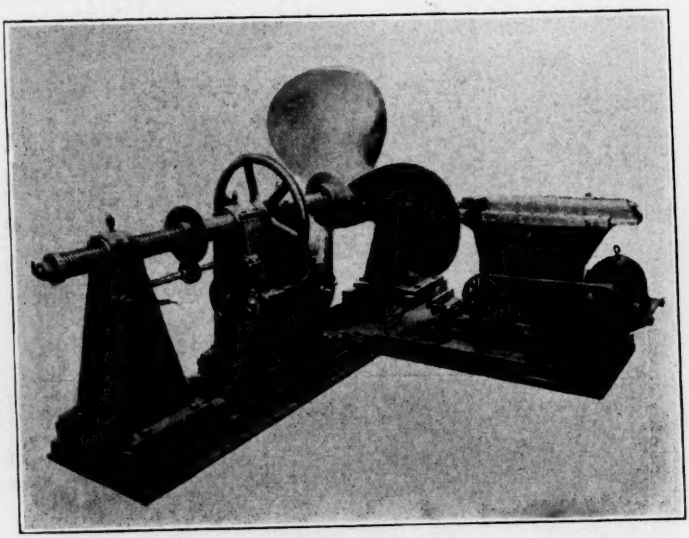


PLATE E.—COSTELLO PROPELLER PLANER.

care is taken at all times to hold the spindle true with pattern leveled and centered.

The drag is then built up, using salmon bricks, as they are soft and absorb a greater amount of water. This stiffens up the loam quickly, which permits faster construction of the mold. If the mold does not stiffen rapidly it retards construction and there is danger of sagging or sliding while green.

The gate is placed in position under one blade leading from the bottom part of the hub to the outside part of the drag. The drag is built up with a solid wall around the outside and mold face, the center being filled in with dry sand and brick bats. Provisions are made for a solid foundation to support the cope lifting plates. The joint is made up smoothly to insure a clean lift.

The pattern is then shifted to the proper position for the second blade. The same procedure is followed on the second and third blades, with the exception of the gate. Only one gate is used. It should be of sufficient size to allow the metal to enter the mold as quietly as possible and fast enough to insure the running of the thin section of the blades.

After the third blade drag is completed, cope lifting plates are placed on the joint, and iron bars are placed between alternate rows of bricks to carry the cope mold face. The outside wall is built directly over the lifting plates for a support to carry the top plate, to which the bottom cope lifting plates are bolted. This enables the lifting of the cope which is removed and placed in a position for finishing. The pattern is then shifted to the other drag, following the same method on all blades.

After all the copes are removed, the pattern is drawn, cleaned and stored. All defects are repaired on the mold face, and tests are placed in the drag, after which a coat of plumbago mixed with molasses water is given the face of the mold to prevent sand from fusing to the casting. The mold is then placed in the oven and held at a temperature of 300 degrees F. for 24 hours to allow the heat to penetrate to the center of the mold, so that it will bake from the inside out, as this prevents excessive cracking on the face of the mold. The temperature is then raised to 400 degrees F. for two days, and then at 450 degrees F. until dry.

The mold is then removed to a casting pit, where a level bed has been struck off. All defects are repaired, copes placed in position, joints made up and dried by keeping a charcoal fire in a drying basket in the hub. This prevents the mold from absorbing moisture. While the mold is being rammed up a covering plate is placed over the down gate. The mold is secured by tying down and the pit is rammed up with backing sand. The fire basket is removed and the mold is given a final inspection. Before placing the center core, a head box is placed in a position of sufficient height to insure feeding of the casting. The core is placed and a runner basin is built. The mold is then ready for the metal.

Large propellers are generally made from scrapped propellers which have been melted down. The metal is analyzed and the necessary additions of zinc, iron, manganese and aluminum are provided for as necessary to insure a correct composition. The metal is melted down in a reverberatory furnace. For a casting that weighs 17,500 pounds, an allowance of 6,500 pounds is made for gates and risers, and a further allowance of about 5,000 pounds to offset loss of metal and to provide a margin of sound metal, so that the furnace charge runs to about 29,000 pounds.

The additions of iron and manganese are made as soon as all of the charge is melted. The zinc and aluminum are added just before tapping. After the zinc and aluminum are added a test is taken for a bend and fracture test. From experience, one can tell if the metal contains too much or not enough zinc. Furnace conditions cause loss of zinc, which makes it necessary to make this test. Approximately 3 per cent loss of the zinc contents is estimated. The metal is then tapped into a ladle, thoroughly stirred and skimmed. Then another bend and fracture test is taken as well as a preliminary test which is sent to the Laboratory.

The mold is poured, taking special precautions to prevent the formation of scruff in the mold. When the metal is in the riser to the height of 12 inches, pouring is stopped. The gate is stopped off and a test is taken from the ladle. The riser is then filled up to about 30 inches above the top of the hub. Molders then churn the metal down to insure a sound casting. The churning continues as long as the metal is in a liquid state, hot metal being added to help keep the riser open.

After the casting operation is finished and the casting has set, the outside of the mold is stripped away. However, care is taken to leave sufficient sand around the casting so as to insure uniform cooling. The mold, with sand covering the propeller, is left in this condition for approximately a week until the metal has cooled sufficiently to touch. The mold is then completely stripped and test pieces and gates are removed. The casting is sent to the Machine Shop with the riser attached, as the simplest operation for the removal of the riser is to perform this operation with a parting tool on a boring mill head when the casting is first set up in the Machine Shop for rough facing of the hub.

The Machine Shop has to produce a finished product out of what it receives from previous hands. Cooperation among the Pattern Shop, Foundry, and Machine Shop can, and usually does in many ways, make the task easier for the Machine Shop. The pattern-maker has made the pitch of his pattern just enough different from the design so that if the Foundry has kept within reasonable limits in its technique, the shrinkage twist of the blades has set them all in just the right direction by exacting the same amount. He has, however, left stock on the pattern where it will do the Foundry the most good, to help to conquer all of the pulls, tears, strains, porous spots and surface flaws. Thus the basis of a fine product is formed. But the machinist may in some ways have a tough job on his hands to save both money and time. His guesses simply have to be right.

Not so many years ago, probably no two shops followed the same mechanical processes to finish propellers. The augmented ship building activity due to the World War found shops everywhere finishing propellers by adaptation of whatever machine tools their facilities afforded with the least derangement of production schedules on heavy work loads. The Philadelphia Yard was no exception. Similar to general outside practice, planing of blades was done by applying fixtures to standard planers with fixed tools and moving work. The slow process complicated the work schedule by tying up standard equipment for times out of proportion to the work done.

In view of the fact that the surface of a constant pitch propeller is actually that developed by a straight line rotating about a fixed axis along which it can slide, so that the ordinates of simultaneous

motion both ways form the tangent of the angle of pitch, the work of producing this surface on a propeller blade can more satisfactorily be done on a shaper than on a planer. This elementary principle and its consequence were recognized some twenty years ago by Mr. George J. Costello, who subsequently became Master Machinist in the Industrial Department, Navy Yard, Philadelphia, which post he held until his retirement in 1931.

After he became Master Machinist, Mr. Costello designed and built a so-called propeller shaper which today is used for most of the machining of propeller blades in the Navy Yard, Philadelphia. In its essentials this machine consists of a horizontal arbor upon which the propeller is fixed through its center of rotation and which is so mounted that the propeller can be rotated and at the same time translated along the line of the axis of the arbor. The shaper head is mounted in the usual manner, so that the tool can be given the appropriate speed and depth of cut. As the tool head reciprocates, it is only necessary to set the control of the arbor so that its simultaneous rotation and translation lengthwise are in the correct proportion to develop the pitch surface desired. This machine, with a maximum cutting speed of about 30 feet per minute, very greatly speeded up the operation of planing blades. It also produces a superior surface of refined accuracy. The only limitation of this machine is its capacity for wheels up to about 8 feet diameter, which, however, has been sufficient except for very large wheels; see Plate E.

For the larger wheels, Mr. Costello applied the same principles to a large Morton draw-cut shaper. On this machine the reciprocating ram has a vertical movement. It was, therefore, necessary to develop a fixture to provide for rotation of the propeller about a fixed vertical axis through its center of rotation. The application of the control to provide simultaneous rotation of the wheel and vertical movement of the ram develops the correct pitch surface.

Before the face of the blades can be machined to develop the designed operation of the propeller, it is correct practice to finish machining the bore of the hub. In this, the first operation of machining propellers, there is the opportunity of applying ingenuity so that other subsequent operations can be done to the maximum extent by machine tools, and that other work is reduced to a minimum.

In setting up for the hub boring operation, the object is to reduce so far as possible the removal of metal from the backs of blades in establishing the designed blade sections. Although the blade surfaces as they come from the mold are reasonably fair, there is usually to be expected some unevenness and some lack of uniformity in thickness. Therefore, in setting up to lay out for the finish machining of the hub bore and the pitch face of the blades, it is the Philadelphia Yard practice to begin this layout on the backs of the blades. The propeller is set on the boring mill table, with the backs of the blades upwards. Center marks are placed on the tips of the blades exactly 120 degrees apart. From the center of the hub to these center marks are scribed radial lines on the backs of the blades. These radial lines are divided at points which on every blade are exactly the same distance from the center. The approximate pitch of the blade surfaces as cast is checked. Then using the center points marked on the tips of the blades, the set up of the propeller on the boring table is adjusted so that if these marks are not in a plane exactly parallel to the table the subsequent machining will be so adjusted to the allowable stock cast in the blade to make all three blades symmetrical. After this adjustment, the points on the backs of the blades are checked for height above the boring mill table so as to determine whether the blades are straight and square. The centerline of the hub bore is then determined. By following this method, when the bore has been finished and the propeller subsequently set up for machining the blade faces, it will be found that the maximum amount of unevenness is eliminated and the minimum amount of work is required on the backs of the blades.

A subsequent operation which is a difficult machinery job requiring particular care is that of cutting long keyways, especially when more than one keyway is required. For proper fit on the shaft taper and for complete interchangeability, the maximum obtainable accuracy is required. For this purpose, it has been the practice to use a special key seating arbor consisting of a cast iron cylinder accurately machined to fit the finished hub bore. In the cylinder is fitted a mandrel which carries a slide to control the motion of a sliding cutter head. The arrangement is set up either on a key seating machine or on a draw shaper, so that the sliding cutter

head is connected by a rod to the machine tool head as a source of power. Two guides are set accurately 180 degrees apart and accurately parallel to the side of the bore taper. As these govern the motion of the cutter head, regardless of the power source, the cutting operation is both rapid and accurate. This practice is still continued as a matter of convenience wherever the fixtures on hand are adaptable to the work. In other cases, however, a more modern set up is available through the recent installation of a Morton 6½-inch keyseating machine. As this machine is standard for general Machine Shop operations, no detailed description is considered to be necessary.

Necessarily, the operations of finishing to contour, the blade backs, blade fillets to hub, and the outside of the hubs proper must be done by hand chipping. Some thought has been given to the practicability of machining the backs of blades in an operation similar to the shaper operation on the pitch surface. This would be a highly desirable development in view of the possible economy and increased accuracy of blade formation which would result. The operation could, of course, be done on a profiling machine if sufficient work were available to justify the investment. A shaper method would be better.

For surface finishing, the standard method long in use was a belt driven felt grinding wheel coated with powdered emery. The wheel, swung from a countershaft and counterbalanced, required two men for its operation. The surfacing had to be done where the wheel could be rigged, regardless of the inconvenience to contiguous activities or of the effect upon them that flying dust might have. The finish, with the wheel in the hands of a well experienced mechanic, was excellent, even though laboriously obtained. This method has, some time since, been superseded by electric driven, flexible shaft disc sanding machines. The use of these disc sanders permits complete freedom in the choice of working conditions. The flat disc instead of the wheel edge simplifies tremendously the surfacing operation. The finish is more quickly done, the surface is far better, and the blade formation is more accurate.

So far as mechanical processes go, the surfacing operation leaves the propeller ready for use. There remains only to check for accuracy of manufacture and for balance. Balancing is now so uni-

versally understood and so commonly practiced that it is sufficient to say here only that in the Philadelphia Yard all wheels, before issue, are accurately balanced both statically and dynamically. The places for removal of metal to compensate for unbalance are matters of choice. The practice at Philadelphia is to select areas which will afford the maximum effect with the removal of the least metal, so as to preserve the best surface contour. It is usually found that dynamic unbalance exposes the existence of a slight excess in blade thickness somewhere and that the unbalance can be readily corrected by removal of metal from the back of the blades, with the assurance that designed blade sections are more nearly reproduced in the product.

In consideration of the care expended on balancing propellers as well as all other rotating mechanisms on naval vessels, it is probably worth while also to consider the permanence of the results initially obtained. There is much effort expended in all sorts of directions to stabilize the behavior of materials. We anneal, we talk of "seasoning." In view of the form of propellers and of the effect of high stresses frequently applied to them, it should not be surprising to find that they are subject to change of shape over a fairly long period of their early life. Propellers, known to have been accurately manufactured, have been removed for repairs and have been found to be out of round in the hub bore. The resultant effect on the pitch has been found to be corrected by reassembly on the shaft taper. It might be worth while, in the interest of satisfactory operation, to check the balance of propellers of high speed ships during the first overhaul after commissioning, if the docking period allows the necessary time.

All of the foregoing has had special application to propellers of constant pitch. Some comment has already been made on the variation of practice required for making propellers of variable pitch except as applied to machining. In machining, the final formation of the blade sections is all that requires different mechanical processes for the two types. Of course, no machine tool cutter operating on a straight line will develop the required pitch surface.

In variable pitch propellers made at Philadelphia, it has been necessary to hold the foundry to the minimum blade thicknesses possible and to require especial care in the molds so that even and

smooth surfaces would result. In the Machine Shop, beyond fairing the pitch face of the blades, these faces have remained as cast. Careful hand grinding with disc sanders has been applied to the backs of the blades with satisfactory results.

The satisfactory production of variable pitch propellers is entirely a matter of economies. Hand work is expensive. If a productive output of variable pitch propellers is required, sufficiently large to justify the application of machine tool work, a profiling machine may be designed for the purpose. Profiling machines, in investment cost, in space demands for installation, and in operation, are expensive. There is probably no other known direction in the way material progress can be made in reduction of cost or in improvement of product than by adaption of profiling work to some of the processes. This procedure will justify itself when the demand develops.

# FACTORS INFLUENCING THE NITRIC ACID TEST FOR STAINLESS STEELS.

By JOHN L. MILLER,* D.Sc.

Several years ago there appeared in a prominent journal† an article describing a test devised for the purpose of determining the corrosion resistance of the stainless alloys. Since that time this test method, because of several inherent advantages enumerated by its author, has become a standard method of determination of proper heat treatment for any particular analysis and has been adopted by many laboratories including the one with which the present writer is connected. Very rigid specifications for maximum weight loss calculated to inches penetration per month have been set forth by purchasers as a requirement for acceptability. As this maximum limit is usually close to the ultimate inherent corrosion resistance under the best conditions of heat treatment, the exact reproducibility of test conditions becomes of great importance.

The test is conducted by immersion of properly prepared samples in 65—67 per cent nitric acid contained in flasks equipped with reflux condensers. The flasks are heated until boiling occurs and maintained at boiling temperature for forty-eight (48) hours, after which the samples are withdrawn, washed, dried, and weighed. Usually at least three such periods are required to establish the corrodibility of a material.

Because of rigid specifications and in view of several discrepancies which had occurred in the course of testing, an investigation of the reproductibility of test results involving consideration of the following factors was undertaken:

(a) The effect of acid amount within the range 300 milliliters to 800 milliliters.

(b) The effect of initial acid concentration within the range 60 to 71 per cent.

* Research Metallurgist, The Babcock & Wilcox Company.

† Corrosion Test for Research and Inspection of Alloys. William R. Huey, Transactions of the American Society for Steel Treating, Vol. 18, page 1126.

(c) The effect of previous exposure of the acid to the action of air.

(d) The effect of using the same acid for more than one test period; or, phrased in another manner, the effect of the presence of impurities in the acid introduced by solution of the sample under test.

(e) The effect resulting from the use of acids from different manufacturers.

(f) The effect resulting from the use of different lots or batches of acid from the same manufacturer.

Samples of stainless steel plate 2 inches × 3/4 inch × 3/16 inch were used for all of the above determinations. These samples were obtained from the center section of two large sheets representing different heats of stainless steel. The chemical analysis made on samples secured from these sheets gave the following values:

| | *Carbon* | *Manganese* | *Phos.* | *Sul.* | *Silicon* | *Chromium* | *Nickel* |
|---|---|---|---|---|---|---|---|
| Heat 1 | .066 | .48 | .024 | .020 | .37 | 20.04 | 10.06 |
| Heat 2 | .058 | .45 | .017 | .015 | .33 | 19.95 | 10.00 |

Both of these heats were known to possess excellent corrosion resistance in the nitric acid test, Heat 1 being somewhat superior to Heat 2.

DETERMINATION OF (A); EFFECT OF ACID AMOUNT.

Samples of plate of Heat 1 were carefully polished, measured, weighed and immersed, two samples in each flask in 300, 400, 500, 600, 700 and 800 milliliters of C. P. concentrated nitric acid (Spe-

TABLE 1.

EFFECT OF ACID AMOUNT.

| *Sample Nos.* | *Amt. of Acid Used (Ml.)* | *Acid Lot No.* | *Acid Maker* | Inches Penetration per Month *1st 48 Hours* | *2nd 48 Hours* | *3rd 48 Hours* | *Total Penetration* |
|---|---|---|---|---|---|---|---|
| 1- 2 | 300 | 1 | A | .00640 | .00763 | .00865 | .0227 |
| 3- 4 | 400 | 1 | A | .00111 | .00075 | .00164 | .00350 |
| 5- 6 | 500 | 1 | A | .00106 | .00116 | .00127 | .00349 |
| 7- 8 | 600 | 1 | A | .00086 | .00095 | .00133 | .00314 |
| 9-10 | 700 | 1 | A | .00098 | .00083 | .00098 | .00279 |
| 11-12 | 800 | 1 | A | .00088 | .00080 | .00121 | .00289 |

Acid renewed each 48-hour period.

cific Gravity 1.42), all taken from the same acid lot. Samples were removed from the flasks at the end of each 48-hour period, dried in alcohol and weighed. The results of this test are tabulated in Table 1, the average for the two samples in each flask being given.

It is evident that up to 700 milliliters an increase in the amount of acid used results in a progressive decrease in the total rate of corrosion. Navy specification for this test states: "at least 500 milliliters." From the data of Table 1, the use of 500 milliliters resulted in a value 25 per cent above that secured with 700 milliliters. Such a variation could easily be the difference between acceptance and rejection.

### DETERMINATION OF (B); EFFECT OF ACID CONCENTRATION.

Samples from both heats 1 and 2 were used. Three acid concentrations were investigated; (a) concentrated 71 per cent; (b) 67 per cent, and (c) 60 per cent. Dilution of the 67 per cent and 60 per cent acid solutions was accomplished using distilled water. Duplicate samples were tested and the results shown in Table 2 are averages. Exactly 700 milliliters of acid solution was used in each flask.

TABLE 2.

EFFECT OF ACID CONCENTRATION.

| *Samples from* | *Acid Concentration (Per Cent)* | Inches Penetration/Month | | *Total Penetration* |
|---|---|---|---|---|
| | | *1st 48 Hours* | *2nd 48 Hours* | |
| Heat 2 | 71 | .00065 | .00056 | .00121 |
| Heat 2 | 67 | .00061 | .00070 | .00131 |
| Heat 2 | 60 | .00053 | .00051 | .00104 |
| Heat 1 | 71 | .00055 | .00067 | .00122 |
| Heat 1 | 67 | .00053 | .00056 | .00109 |
| Heat 1 | 60 | .00045 | .00050 | .00095 |

The constant boiling composition for solutions of pure nitric acid and distilled water is at 67.6* per cent nitric acid. This solution boils at a temperature of 121.9 degrees C. (251.4 degrees F.). It is evident that the 60 per cent acid strength is definitely less corrosive than the other two which suggests that the acid strength has remained unchanged during test due to efficient condensation of the vapors.

* International Critical Tables, Volume 3, page 309, Reference 10.

DETERMINATION OF (C); EFFECT OF PREVIOUS EXPOSURE OF THE ACID TO THE ACTION OF AIR.

It was thought that exposure of the acid to air for a period of time before using might affect the result. Two five-pound bottles from the same acid lot were selected. One was stoppered between the 48-hour periods, but the other bottle was allowed to remain exposed to the air for 48 hours before use. The samples used were from Heat 1 and 700 milliliters of concentrated (71 per cent) acid were used. The results of this test shown in Table 3 indicate that continued contact with air does not affect the corrosion values.

TABLE 3.

EFFECT OF EXPOSURE OF ACID TO AIR.

| | Inches Penetration per Month | | | Total |
|---|---|---|---|---|
| *Acid Condition* | *1st 48 Hours* | *2nd 48 Hours* | *3rd 48 Hours* | *Penetration* |
| Exposed to air before use | .00074 | .00068 | .00085 | .00227 |
| Not exposed | .00066 | .00076 | .00096 | .00238 |

DETERMINATION OF (D); EFFECT OF USING THE SAME ACID FOR THREE 48-HOUR TEST PERIODS.

This test was for the purpose of determining the acceleration of attack caused by the introduction of impurities into the nitric acid due to solution of the sample under test. Samples were taken from the plate of Heat 1 and tested, two in a flask in 500 milliliters and 700 milliliters of C. P. concentrated (71 per cent) nitric acid. For one set of samples the acid was changed at the end of each 48 hours. For the other set boiling was continued for 144 hours. The results shown in Table 4 give a weight loss of over 12 times as much for the samples continuously tested without acid renewal. The results also indicate the effect that area of samples exposed has on corrosion values, the greater the area exposed the higher the corrosion value for any given sample. In all tests described herein the total area exposed in one flask has been approximately 8 square inches.

TABLE 4.

RESULTS OF CONTINUOUS TESTING *vs.* INTERMITTENT TESTING WITH ACID CHANGES.

| *Acid Amt. (Milliliters)* | *Method of Test* | *Total Inches Penetration* |
|---|---|---|
| 500 | Three 48-hour periods with acid changed each 48-hour period | .00349 |
| 500 | One 144-hour period | .0473 |
| 700 | Three 48-hour periods with acid changed each 48 hours | .00279 |
| 700 | One 144-hour period | .0332 |

DETERMINATION OF (E); EFFECT OF USE OF ACID FROM DIFFERENT MANUFACTURERS.

Bottles of C. P. nitric acid were secured from five different nitric acid manufacturers. Samples of Heat 1 were immersed, two in a flask, in 700 milliliters of each of the concentrated acids. The acid was changed each 48-hour period. The results of this determination are given in Table 5.

TABLE 5.

EFFECT OF THE USE OF DIFFERENT BRANDS OF C. P. NITRIC ACID

| *Acid Manufacturer* | ←Inches Penetration per Month→ *1st 48 Hours* | *2nd 48 Hours* | *3rd 48 Hours* | *Total Penetration* |
|---|---|---|---|---|
| A | .00098 | .00083 | .00098 | .00279 |
| B | .00064 | .00055 | .00070 | .00189 |
| C | .00089 | .00102 | .00179 | .00369 |
| D | .00066 | .00105 | .00093 | .00263 |
| E | .00069 | .00089 | .00120 | .00278 |

The highest value secured is 95 per cent greater than the lowest value. The other three values average 45 per cent above the lowest value.

DETERMINATION OF (F); EFFECT OF THE USE OF DIFFERENT LOTS OF ACID FROM THE SAME MANUFACTURER.

Four different lots of C. P. nitric acid made by Manufacturer A were used. Samples representing both Heats 1 and 2 were used. In all cases 700 milliliters of the concentrated acid was used and renewed each 48-hour period. These results, given in Table 6, show a maximum difference for Heat 1 of 22 per cent and for Heat 2 a difference of 27 per cent.

TABLE 6.

EFFECT OF DIFFERENT ACID LOTS FROM ONE MANUFACTURER.

| *Sample Heat No.* | *Acid Lot Used* | *Inches Penetration per Month* — *1st 48 Hours* | *2nd 48 Hours* | *3rd 48 Hours* | *Total Penetration* |
|---|---|---|---|---|---|
| 1 | 1 | .00098 | .00083 | .00098 | .00279 |
| 1 | 2 | .00058 | .00056 | .00114 | .00228 |
| 1 | 3 | .00066 | .00076 | .00102 | .00244 |
| 1 | 4 | .00085 | .00073 | .00105 | .00263 |
| 2 | 1 | .00087 | .00120 | .00189 | .00396 |
| 2 | 2 | .00075 | .00080 | .00156 | .00311 |
| 2 | 3 | .00062 | .00099 | .00151 | .00312 |
| 2 | 4 | .00083 | .00104 | .00161 | .00348 |

## SUMMARY.

Investigation of the factors influencing the corrosion values secured in the testing of a particular stainless steel in boiling nitric acid has led to the following conclusions.

The amount of nitric acid used in relation to the surface area of steel exposed has a major effect in determination of the values secured. This is due to the fact that the presence of impurity in the acid introduced by solution of the sample greatly accelerates the corroding action. Some standard relation between area of samples and liquid volume must be used to secure comparable results and it is proposed that this relation be one and one-half square inches of exposed area to each 100 milliliters of concentrated acid.

The initial acid composition should be 67 per cent concentrated acid or over as weaker concentrations give low values.

Previous exposure of the acid to air is of no importance.

Periodic acid changes must be made during progress of the test to limit the amount of impurity in the acid resulting from sample solution. The 48-hour periods usually used are satisfactory.

Considerable variation in test results on a particular sample may occur due to the use of acids from different manufacturers and slight variations occur due to the use of different lots from the same manufacturer. The presence of traces of certain impurities such as hydrochloric and sulphuric acids or salts of iron, nickel, chromium, and other metals may cause variations out of all proportion to the amount present.

Whenever a rigid weight loss specification must be met and values slightly exceed the maximum allowable the use of another acid may place the result well within specifications.

# PIPE COVERING MATERIALS FOR HIGH TEMPERATURES.

By RALPH R. GURLEY, LIEUTENANT, U. S. N., and
W. P. SINCLAIR, ASST. MECH. ENGR.

For many years the standard Navy pipe covering material has been 85 per cent magnesia. The ease with which this material can be applied in pipe covering form, its low heat conductivity, its relatively low cost, and its comparative lightness in weight have all been factors favoring its retention as the standard covering. The temperature range to which this material is adaptable, however, is limited. At temperatures in excess of 500 degrees F., it calcines and decomposes. Therefore, when the Navy began to contemplate the use of steam with temperatures in excess of 500 degrees F., it became necessary to investigate and to adopt other types of heat insulating materials for pipe coverings. These materials are not only required to have highly efficient insulating properties, but also thermal and physical properties which do not deteriorate on subjection to the higher temperature ranges.

The materials which have been approved and are now used in the Service as pipe coverings for temperatures above 500 degrees F. are grouped into the following categories:

(1) Sectional and segmental molded pipe covering.
(2) Felted mineral wools.
(3) Aluminum foil, (limited approval).
(4) Insulating cements.

Most of the molded pipe coverings are composed of large percentages of diatomaceous silica and magnesium or calcium carbonate bonded together with small percentages of asbestos fibers. One very efficient material of this type, in addition to the above constituents, contains bloated flakes of mica. The molded pipe coverings are furnished to the Navy in standard pipe sizes and standard thicknesses, made in cylindrical sections 36 inches long, split in half

lengthwise. General Specifications for Machinery prescribe the thicknesses to be employed for different pipe sizes and temperatures. Double layers of pipe covering are specified for high temperature conditions (over 500 degrees F.) on standard pipes from 4 to 10 inches in diameter. Where double layers are specified, it is customary for the manufacturer to supply an inner layer of high temperature material, and an outer layer of 85 per cent magnesia. This reacts to the manufacturer's advantage, because 85 per cent magnesia is cheaper than diatomaceous earth. It is advantageous to the Navy because the combination cover weighs less than a complete high temperature cover. The high temperature materials, with two exceptions, are not as good insulators as 85 per cent magnesia; hence, in general, the combination cover gives better heat insulation than a complete high temperature covering would give for the same thickness of cover.

Mineral wools consist of rock fibers made from a dolomite rock composed of calcium and magnesium oxides and silicates. The rock is melted and blown in a steam spray. The resulting fibers are similar in appearance to spun glass and are equally brittle. This type of material has very little tensile strength. It is made up in the form of a blanket and is secured to a wire screen outside cover in much the same manner as the filler is secured inside the ticking of a mattress. Narrow strips of screen wire, running the length of the section of pipe covering on its inner side, are secured to the outer screen cover by wires passing through the rock wool blanket. The covering is wrapped around the pipe in a single layer and the abutting edges of the outer wire screen are secured by lacing or some type of clip. It is imperative, in using this type of cover, that it be fitted snugly to the pipe to prevent damage from vibration.

Aluminum foil was used in Germany for high temperature insulation before it was introduced in this country. The heat insulating value of an aluminum foil cover will vary widely with the manner of application of the foil and with the degree of expertness with which the application is made. In its most effective form aluminum foil is applied without crumpling. The successive layers are made of individual sections of foil separated from each other by bands of heat resisting material 3/8 inch thick and about an inch wide.

These bands are built up around the pipe as the successive layers of foil are applied and eventually support the sheet metal protecting cover.

The cost of application of aluminum foil in this manner is too great to be practical. For its insulating value in practical installations, it depends in part on the reluctance of a bright surface to absorb and radiate heat and in part on the opposition to convection currents presented by the small air cells formed between adjoining layers of crinkled foil. Aluminum foil 0.0032 inch thick, embossed with diamond shaped figures, is crinkled by hand and partially straightened out. It is then wrapped lightly around the pipe so that each successive layer occupies a space of about ⅜ inch and makes only point contacts with the next inner layer. Any number of layers may be applied, depending on the protection desired and on the allowable bulk of installation. The entire foil covering must be protected by a sheet metal housing to prevent damage to the fragile foil. This housing is supported directly from the pipe by small sheet metal "towers."

The big advantage of aluminum foil pipe coverings over other types lies in the reduction in weight which can be effected. This advantage is much reduced, if not entirely lost, with small sizes of pipe because of the increased percentage of the total weight of the installation represented by the "towers" and the sheet metal protector. With this type of insulation, higher cover temperatures are encountered than in the case of the molded and rock wool materials, because of the reluctance of the metal cover to radiate the heat transmitted to it.

Insulating cements are made up of widely variant materials. As a result they vary markedly in their specific weights, their insulating qualities, and other physical characteristics. In general, this type of heat insulating material may be divided into the following groups, according to the basic constituent:

(*a*) Asbestos cements.
(*b*) Diatomaceous earth cements.
(*c*) Mineral and slag wool cements.

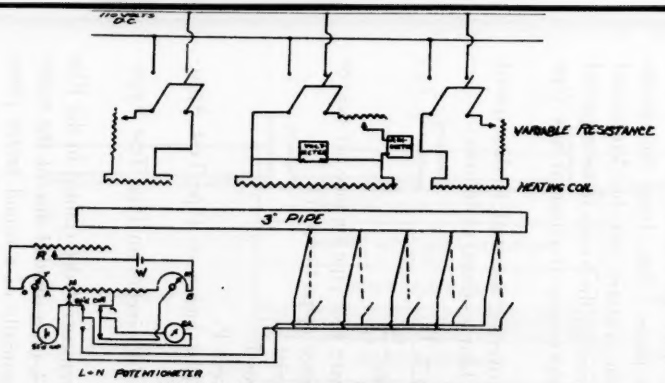
Although varying greatly among themselves in heat conductivity and weight, they are generally higher than the molded pipe covering in both respects.

The suitability of the material for patchwork, where other materials can not be employed, justifies its use at a sacrifice of heat protection and weight, within certain limits.

From among these four categories of high temperature pipe insulating materials, the Navy selects by means of "approval tests" the materials which best meet the Service requirements. Materials which pass the specified tests are placed on the Bureau of Engineering Approved List of Insulating Materials. Approval is based on tests conducted at the U. S. Naval Engineering Experiment Station at Annapolis. The approval test consists of a thorough investigation of the suitability of the material for use as a pipe covering on board ship. Tests are conducted to determine shrinkage and loss of weight under heats as high as 1500 degrees F.; resistance to erosion and vibration; tendency to absorb and retain moisture; and change in hardness after heating to 1200 degrees F. These tests are all designed to insure that the covering will have a satisfactory structure to meet all conditions of service. They have only a general bearing on insulating qualities. The true value of the material as a heat insulator is dependent on its heat conductivity and is determined on the Pipe Test Apparatus.

The Pipe Test Apparatus, Figure 2, which was built at this Station in 1925, consists of a 36-inch section of 3-inch standard wrought iron pipe, to which the covering under test is applied. Inside of this pipe there are three heating coils wound around an insulated 2-inch steel pipe of the same length. Two of the coils are so wound that each covers a 3-inch end section of the 2-inch pipe. The third coil covers the 30-inch middle section. The 2-inch pipe, on which the coils are mounted, is centered in the 3-inch pipe and the ends of the 3-inch pipe are closed with insulating discs.

A variable resistance connected in series with each coil affords means of regulating the heat supplied to each coil. The power input to each coil is adjusted until the temperature of the pipe over the end coils is the same as that over the central coil. Hence, corrections for end losses are eliminated and the heat supplied to the central coil is dissipated radially through the central 30-inch section of the covering. Iron constantan-thermocouples are used for measuring the temperatures of the inner and outer




WIRING DIAGRAM OF TESTING APPARATUS

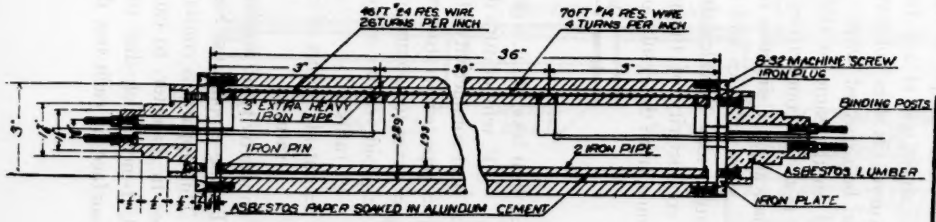



FIGURE 2

APPARATUS FOR TESTING HEAT INSULATING PIPE COVERING MATERIAL

UNITED STATES NAVAL ENGINEERING EXPERIMENT STATION
ANNAPOLIS, MD.

APPROVED
OFFICER IN CHARGE

SCALE
DATE: JUNE 28, 1921
DRAWN BY: E.W.H.
TRACED BY: R.B.P.
CHECKED BY: W.F.S.

| TEST NO | PAGE NO | CODE | DRAWING NO |
|---|---|---|---|
| | | 3 | 9 3196 |

surfaces of the covering. The power input to the central heating coil is computed from voltmeter and ammeter readings. The heat loss through the cover is expressed in B.t.u.'s per hour per square foot per degree Fahrenheit temperature difference (pipe to room). A heat loss curve for the material under test is developed by making runs at several different pipe temperatures, *viz.*, 400, 600, 800 and 1000 degrees F. The heat loss curve represents the B.t.u.'s lost per square foot of pipe surface per hour per degree F. temperature difference (pipe to room) for the particular thickness of material under test at any temperature difference over the range of the curve. It does not give any information regarding the heat losses to be expected when using other thicknesses of the same material on the same or different pipes. But, from the results of this test, the conductivity of the material can be determined mathematically. Using this conductivity, the losses to be expected from all sizes of pipes and all thicknesses of cover at any pipe temperature may be calculated.

The conductivity of the pipe covering material is determined by formula from the results of the heat loss test, as follows:

$$h = \frac{k\,(T_1 - T_2)}{r_1 \log_e \frac{r_2}{r_1}} \quad . \quad . \quad . \quad (1)$$

$h$ = heat loss, B.t.u.'s per square foot pipe surface per degree F. temperature difference (pipe to room).

$k$ = heat conductivity of material.

$T_1$ = pipe temperature, degrees F.

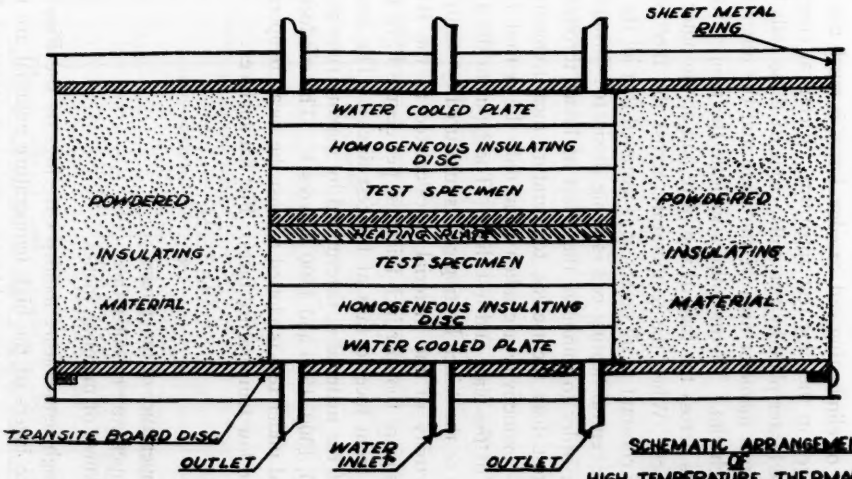
$T_2$ = cover temperature, degrees F.

$r_1$ = inside radius of cover (3.3 inches on Pipe Test Apparatus).

$r_2$ = outside radius of cover (6.3 inches on Pipe Test Apparatus).

The conductivity of insulating cements is determined in the Flat Plate Testing Apparatus, Figure 3, on a molded disc of the materials. This apparatus consists essentially of a round heater plate, 8 inches in diameter, to each side of which is applied a similar shaped, 1-inch thick disc of the material to be tested. To the outer surface of each test disc there is applied a similar disc of

SERIAL No. EES-6003




SCHEMATIC ARRANGEMENT OF HIGH TEMPERATURE THERMAL CONDUCTIVITY CELL

SCALE ½ FULL SIZE

FIGURE 3

U.S.N. ENGINEERING EXPERIMENT STATION
ANNAPOLIS, MD.
DRAWN BY R.T.J. MARCH 13, 1928
TEST NO. 6003 PLATE NO. 3
DRAWING NO. 4426-3-9

homogenous insulating material. To the outer surface of each homogenous insulating disc there is applied a water cooled plate of the same diameter. The entire assemblage of heater plate, test pieces, homogenous material, and cooler plates is supported in a vertical pile in a sheet metal receptacle and packed with diatomaceous earth.

The method of eliminating end, or edge, losses is much the same as that employed in the pipe test apparatus. Electrical energy is supplied to the heater plate by two coils. One of these coils heats the central 6-inch diameter area of the plate and the other heats the outer 1-inch rim. Thermocouples indicate the temperature at different points across the face of the plate and at the outer face of the test discs. When the temperature across the face of the heater plate is constant at all points, it is assumed that all the heat supplied to the central heating coil is being dissipated through the test discs. In order to minimize the effect of losses through the edges of the test discs themselves, temperature measurements for calculation of conductivity are taken from only the central 4-inch diameter area of the plate and test discs. The input to the 4-inch central section of the 6-inch heating coil is measured by wattmeter.

The conductivity of the material is calculated as the B.t.u.'s per hour per square foot per inch thickness per degree F. of mean temperature (from face to face of the test discs). The conductivity curve of the material is determined by making runs at 500, 700, 900, 1100, 1300, 1500 and 1800 degrees F. The conductivity of the material under test is plotted against the mean temperature of the high and low temperature faces. For flat surfaces:

$$h = \frac{k\,(T_1 - T_2)}{x} \quad . \quad . \quad . \quad (2)$$

$T_1$ = temperature of inner face.
$T_2$ = temperature of outer face.
$x$ = thickness of material, inches.

In testing high temperature molded coverings on the Pipe Test Apparatus, two layers of the high temperature material are used. Combination covers are not tested because the conductivity so determined would apply only to that particular set-up and would not be the conductivity of the high temperature covering alone. How-

ever, it is possible to compare heat losses through combination covers with those through homogeneous covers without further practical tests. The method of computation is beyond the scope of this article.

In Figure 1 are delineated the bands of conductivity curves of the four different categories of pipe covering materials as deter-

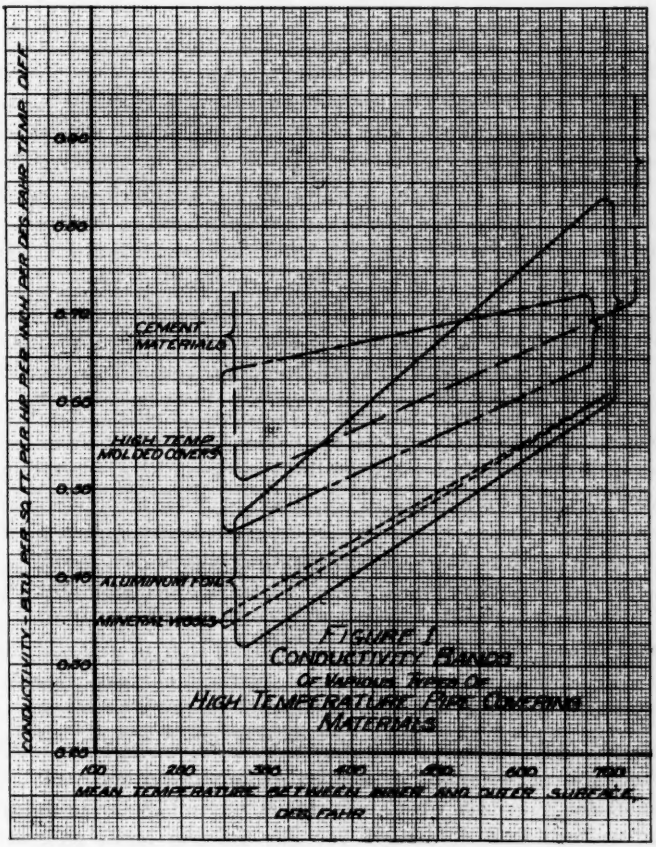



FIGURE 1
CONDUCTIVITY BANDS OF VARIOUS TYPES OF HIGH TEMPERATURE PIPE COVERING MATERIALS

mined on the 3-inch Pipe Test Apparatus and the Flat Plate Testing Apparatus at the Engineering Experiment Station. These results studied in conjunction with the physical tests for structural strength, moisture absorption, resistance to change under heat, etc., constitute the basis for approval or disapproval of heat insulating materials submitted for use in the Naval Service.

# PRESSURE DROP THROUGH A 10½-INCH BORE, BUREAU DESIGN, GLOBE VALVE.

By MASON S. NOYES, MEMBER.*

The cost of maintaining steam stop valves, on vessels of the fleet, in satisfactory operating condition became so excessively high about six years ago, that the Bureau of Engineering decided to investigate the design of the valves then in service, with the view of developing an improved design, as free as possible from all features contributory to the difficulties experienced.

The task of developing the new design was assigned to the mechanical drafting section of the Bureau. A careful and thorough study of the problem was made, including an investigation of the best commercial practice. The Bureau was greatly aided in its work by the lively interest and cooperation of several leading valve manufacturers, who made many valuable suggestions.

The principal requirements for the new design were:

(1) A compact and rigid body of a shape that would expand uniformly in all directions and not distort at the operating pressure and temperature, or due to the force applied through the stem when closing the valve.

(2) A disk of rigid construction to prevent warping, positively guided throughout its travel to assure proper seating.

(3) A high lift for the disk to assure ample steam passage.

(4) A steam flow through the valve as free as practicable from abrupt changes in direction.

(5) Some form of differential gear for operating the larger valves, in order to assure sufficient seating force for tightness.

The work on the design culminated several years later in a series of valves for 300 pounds per square inch, gage, maximum working steam pressure and 750 degrees F. total temperature,

* Design Division, Bureau of Engineering.

known as Bureau Standard B-149, which was immediately followed by another series suitable for 400 pounds per square inch gage maximum working steam pressure and 750 degrees F. total temperature, known as Bureau Standard B-150.

Owing to the type of guide adopted for the disk, the question as to whether any saving had been made in the pressure drop through the valve was so very much a matter of opinion that the Bureau decided to have one of the valves tested under actual working conditions at the Naval Boiler Laboratory, to ascertain the pressure drop through the valve at various velocities, pressures and mass rates of flow. The valve selected for the test was a 10½-inch bore globe valve, designed for 300 pounds per square inch, gage working steam pressure and manufactured by the Crane Co., of Chicago, Ill., in strict accordance with Bureau Standard B-149. The valve had previously been installed on the U. S. S. *Luce*, where it underwent a highly satisfactory test at sea under service conditions of six months' duration.

As indicated in Figure 1, the Bureau's design differs in external appearance from the conventional valve in the inclination of the valve stem, in contrast to the usual position normal to the axis of the valve. This inclination reduces the change of direction in the flow of the steam passing through the valve. In the interior of the valve it will be noticed that the valve seat and the dividing wall have this same inclination. The valve disk is of a particularly robust type guided throughout its travel by a "liner." The lower portion of this liner originally was provided with six openings or ports just above the valve seat, all of equal area and equally spaced around the circumference.

The valve was installed at the Naval Boiler Laboratory in the main steam line as sketched in Figure 2. It was set up in such manner that the steam entered the valve above the disk. The instruments used in connection with obtaining data on the valve itself were installed at the valve as shown and included 2 calorimeters, 2 Bourdon-type pressure gages, and a thermometer. The weight of the valve was found to be 1920 pounds, and this load, together with the proper provision for the movement of expansion and recoil of the main steam line at the proposed steam flow rates, neces-

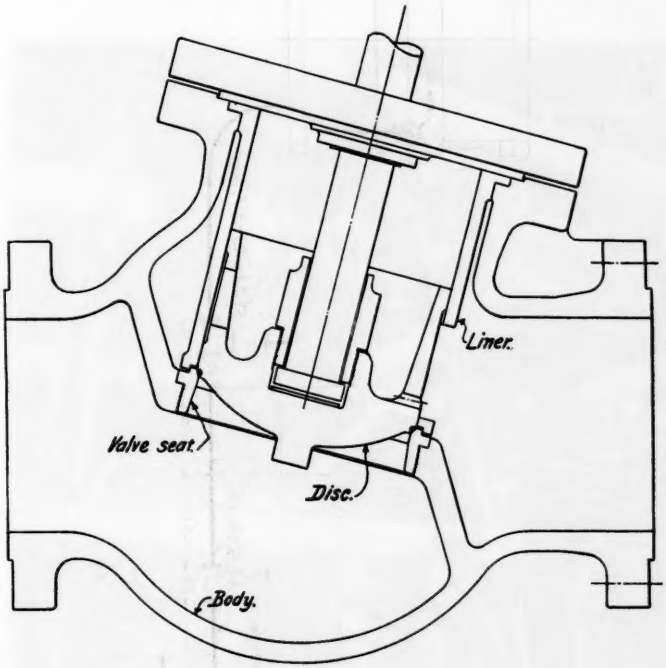



FIG. 1

sitated considerable bracing. This support was provided by structural steel sheer legs as shown in Figure 3.

It was desired, at first, to pass as much as 360,000 cubic feet of steam per hour through the valve. The boiler available for the test could be operated to produce a maximum of 200,000 pounds of saturated steam per hour at 300 pounds per square inch gage. The capacities of the condensing, air flow, and distilled water equipments, however, made operation at this steaming rate somewhat difficult and expensive for more than brief intervals. Allowing about 10 pounds for a pressure drop through the main steam line from the boiler dry pipe to the valve under test, this steaming rate would be equivalent to only 308,000 cubic feet of steam flow.

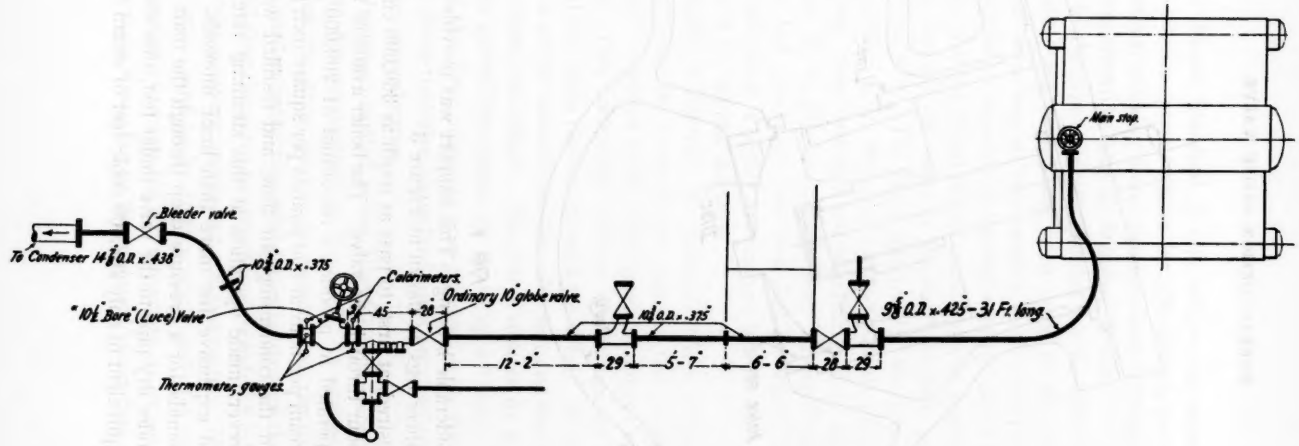

Bleeder valve.
To Condenser 14⅜ O.D. x .438"
10¾ O.D. x .375
Calorimeters.
"10½" Bore" (Luce) Valve
45°
28
Ordinary 10" globe valve.
10¾ O.D. x .375
Main stop.
9⅝ O.D. x .425 - 31 Ft. long
Thermometers, gauges.
12'-2"
29"
5'-7"
6'-6"
28"
29"

FIG. 2

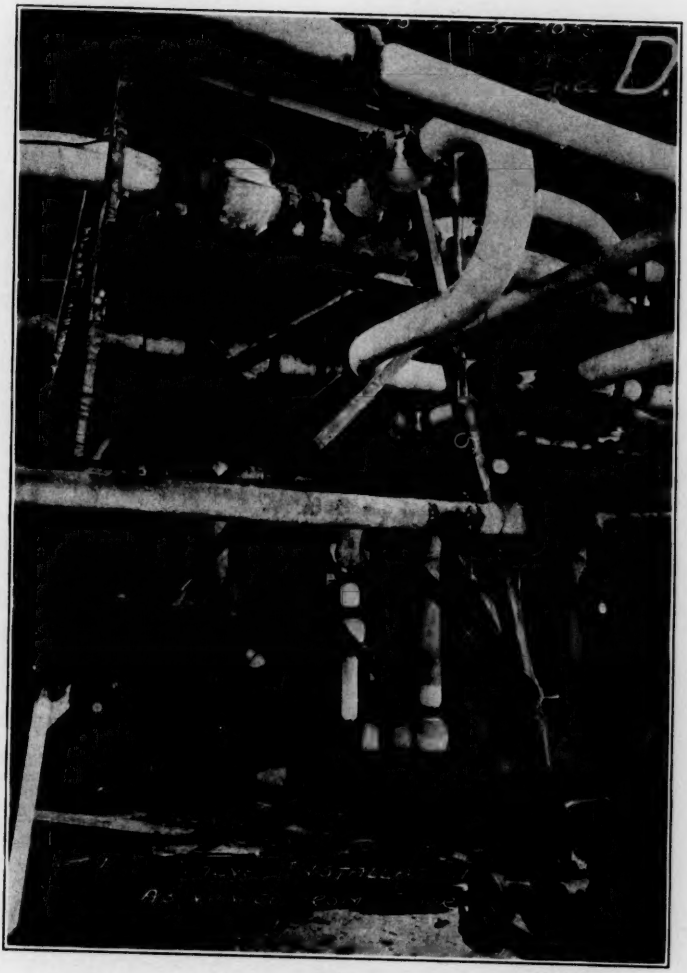



FIG. 3.

The Naval Boiler Laboratory proposed, therefore, to test the valve at four different pressures with four different weights of steam flow—or a total of sixteen different volumes of steam flow per hour. This was accepted and the tests were made under the following approximate conditions:

Pressures in pounds per square inch, abs.

| 290 | 265 | 215 | 165 |
|---|---|---|---|

Steam flow in pounds per hour, approximately

| 52,000 | 100,000 | 150,000 | 200,000 |
|---|---|---|---|

At the maximum steam flow at maximum pressure it was necessary to conduct the test at 280 instead of 290 pounds per square inch at the valve entrance in order to keep within the setting of the boiler safety valves.

The results of these tests are shown in Plate I, and also in Plates II and III by the curves marked A1, A2, A3 and A4. It will be noted that the steam velocities varied between 2500 feet per minute and 16,700 feet per minute, depending on the pressure and mass rate of flow.

Though it was felt that these results indicated that the design compared favorably with other valves designed for similar service (at least as far as pressure drop for the rates of flow and specific volumes used were concerned), it was believed, nevertheless, that further improvement could be obtained. Therefore, the liner of the valve was modified by removing three alternate bridges between the ports or openings, commencing with the bridge which was nearest and directly in line with the center of the valve inlet. At the same time a direct comparison was desired with a valve of very nearly equal size and of the Bureau's older Standard B-137 design. The ordinary 10-inch globe valve, indicated in Figure 2, which handled all the steam supply to the valve under test was selected for comparative test. Because of other more urgent laboratory tests, nine runs were made quickly and forwarded by letter report. This second test series was run at pressures of 165, 264, and 288 pounds per square inch, absolute, and with mass steam flows varying from 50,000 to 199,000 pounds per hour. The results are as shown in Plates II and III, the "B" curves for the

new design test valve, and the " C " curves for the ordinary valve of the older design.

It was thought that these two bridges of the modified liner, to the right and left of the valve inlet, might tend to restrict flow of steam to the far side of the seat and the next test was conducted for the purpose of learning whether improvement would be secured by turning the liner 60 degrees so that one of the bridges would be nearer to and directly in line with the center of the valve inlet. Following this test, another was made with the liner removed, to learn, if possible, just what effect on the pressure drop the liner really did have. It was also proposed, to change the material for the liner to " Ni-Resist," a nickel-copper-chromium cast iron, an austenitic material which is non-galling and unusually resistant to corrosion and erosion when the nickel content is in the neighborhood of 12 per cent. Also the arrangement of the ports or openings were modified to provide one large 120 degree aperture next to the valve inlet and two equal lesser apertures of 75 degrees on the opposite side of the liner.

Nine test runs were made on the valve without the liner: Three at about 166 pounds per square inch absolute and at rates of about 93,000 and 126,000 and 180,000 pounds per hour, three at about 264 pounds and three at 290 pounds, all the latter with, roughly, the same mass flow rates. These results are not shown.

The " Ni-Resist " liner then was installed and fifteen test runs were made, about as follows:

| *Pressure, lbs. per sq. in., abs.* | *164* | *264* | *289* |
|---|---|---|---|
| Mass Steam Flow, in pounds per hour | 48,000* | 90,000* | 90,000* |
| | 92,500 | 92,000* | 91,000* |
| | 93,500 | 139,000 | 138,000 |
| | 143,500 | 159,000 | 158,000 |
| | 161,000 | 189,000 | 190,000 |

Those marked with an asterisk (*) were rejected as having measured pressure drops of about the magnitude of the probable error in the measurement of the pressure drop. These results are plotted as the " D " series of curves, Plates II and III.

The original intention of the tests was simply to determine the pressure drop through the Bureau's standard valve under the best practical test conditions. Considering the time and expense involved, it was felt that other interesting information could be obtained, hence the comparative test with an ordinary valve. However, this comparison is not a fair one, since the Bureau standard valve has a 10½-inch bore and the ordinary valve has a 10-inch bore. In order to obtain a true comparison, two sets of formulae were worked out, the first being empirical, and the second rational. These formulae make possible the prediction of drops through other sizes of valves of the same general design, eliminating the need of actual tests.

The empirical form expressed the data in the form of the resultant "losses in available energy" with the object of readily predicting the amount and cost of this loss. The following empirical equations were set up according to the pressure at the valve entrance:

| PRESSURE | FORMULAE |
|---|---|
| 290 lbs. per sq. in. abs. | $Y = (9.527 \times 10^{-10}) M^{1.751}$ |
| 265 lbs. per sq. in. abs. | $Y = (7.289 \times 10^{-10}) M^{1.790}$ |
| 215 lbs. per sq. in. abs. | $Y = (3.014 \times 10^{-10}) M^{1.903}$ |
| 165 lbs. per sq. in. abs. | $Y = (1.585 \times 10^{-10}) M^{1.993}$ |

in which "Y" is the number of available B.T.U. lost per pound of steam and "M" is the mass steam flow in *thousands* of pounds per hour.

The second form gave the pressure drop directly by means of a rational formula showing the relation between the pressure drop, the mass steam flow, the specific volume of the steam at the valve, and some conveniently chosen linear dimension of the valve. This formula was derived at the Naval Boiler Laboratory, by the use of dimensional analysis. This equation is in the form of $p = km^2s/l^4$ where "p" is the pressure drop in pounds per square inch.

"k" is a constant.

"m" is the mass steam flow in pounds per *second*.

"s" is the specific volume of the steam at the valve in cubic feet per pound.

"$l$" is any conveniently obtained linear dimension of the valve, as indicated above.

In the present case the bore at the valve inlet is taken as the linear dimension. In any series of geometrically similar valves comparison between the different sizes of valves may be made equally as well by selecting the bore of the valve seat, or the diameter of the circle of contact between disk and seat in preference to the bore of the inlet. However, in no case should a comparison be attempted by taking, for instance, the bore of the valve seat for one size of valve in the series and the bore of the inlet end for the other valve.

While the difference between the pressure drop as predicted by the rational formula and the pressure drop observed on test was less than one pound for almost all observations, due to practical conditions the test readings can be taken as correct only to about $\pm$ 1 pound. The formula is therefore apparently substantiated.

Although an empirical equation generally can be made to fit one limited set of observations more accurately than can a rational equation, the former can rarely be trusted much beyond the range of its own observations. Extrapolation beyond this range becomes increasingly uncertain. On the other hand, a rational equation, as a deduction from a general law of nature, applies universally, and justifies a greater extrapolation. For this reason a rational equation is generally preferable and is used to present all the data from the tests in connection with the Bureau type valve.

One other factor weighed equally as heavily in presenting all the data in the form of the rational formula. In design work anyone who has to consider the main steam piping conditions of a power plant is more concerned with the total pressure drop and total loss in available energy between the main steam generators and the main power unit's throttle or control valve than he is in the individual loss in available energy through any one valve or fitting in the line of piping. The valve manufacturer, for his part, is bound to be more interested in a quick and easy comparison of pressure drops, especially since the valve design having the lowest constant " k " would give the least pressure drop—and incidentally the least loss in available energy—for the same conditions of mass flow and specific volume. Moreover, as a " selling point," pressure drop is more generally and easily appreciated by both sales engineer and buyer's representative.

FUEL OIL TESTING PLANT TEST 3068

# EXPERIMENTAL GLOBE VALVE (CRANE) 10½" BORE

ENCL. H.

PRESSURE DROP THRU VALVE WHEN FULL OPEN — ENTRANCE PRESSURE ON VALVE DISC — AT THE RATES OF STEAM FLOW AND ENTRANCE PRESSURES INDICATED (SEE NEXT PAGE)

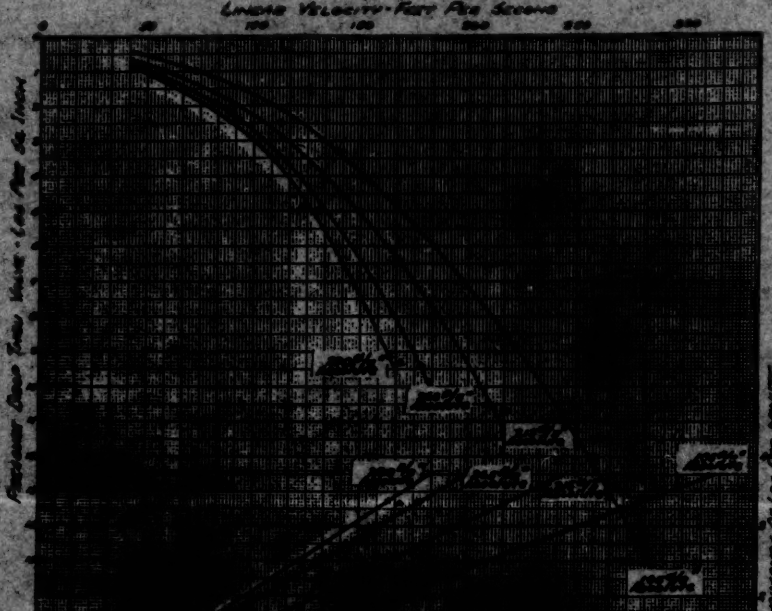


PLATE I

Mass Stream Flow in Lbs. per Second

PLATE II.

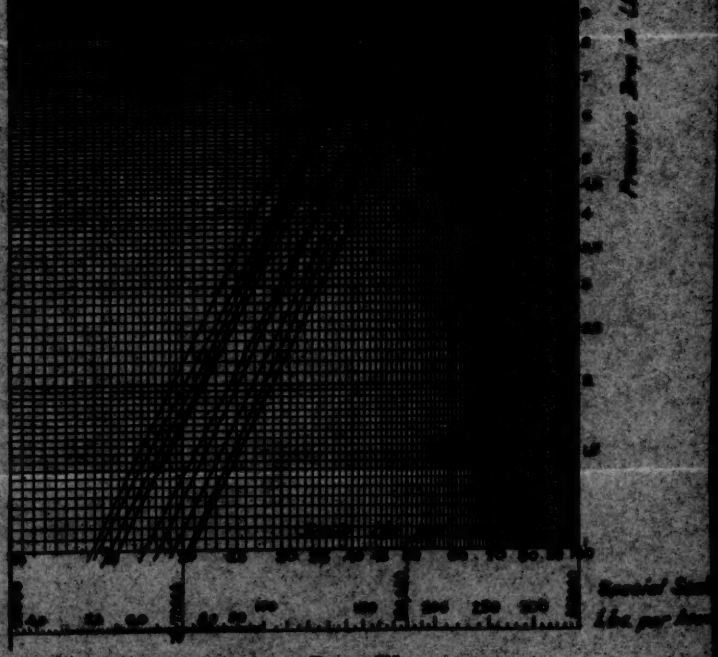


PLATE III.

In the present case, where the same valve was used throughout, the rational formula may be simplified to the form

$$p = cm^2s$$

where c = an experimentally determined constant which is actually equal to $k/l^4$.

The geometric mean value of the constant "c" for the most reliable of the sixteen test runs made is $1.668 \times 10^{-3}$. It has further been estimated that the "probable error" of this mean "c" = $0.022 \times 10^{-3}$.

No values for the constant "k" of the rational formula as first derived, have been given, not so much because the tests were conducted on just one size of valve but because the constant "k" depends, in actual value for any one series of geometrically similar valves, upon the particular linear dimension "c" chosen by the designer to represent the relation in linear size between the valves in the series.

# CHARTS FOR THE DETERMINATION OF PER CENT EXCESS AIR AND PER CENT THEORETICAL OXYGEN ACCOMPANYING PER CENT $CO_2$ IN THE FLUE GASES WHEN FIRING ANY FUEL OIL.

By Samuel Letvin.*

The purpose of these charts is to enable quick, accurate determination of per cent excess air and per cent theoretical oxygen accompanying per cent $CO_2$ in flue gases when firing fuel oil. This method requires neither formulae, ultimate analyses, nor flue gas oxygen determinations. The sole requisite is $CO_2$ percentage. It is particularly applicable, therefore, for use in connection with automatic $CO_2$ indicators and recorders, large numbers of which are now in operation in marine as well as stationary installations.

An example of the determination of per cent excess air being used and per cent theoretical oxygen accompanying per cent $CO_2$ in the flue gas by means of the charts is as follows: (See charts for directions.)

$CO_2 = 13.3$ per cent.

Specific gravity of the fuel being fired at 60 degrees/60 degrees F. = .89.

Theoretical maximum $CO_2 = 15.6$ per cent.

Per cent excess air = 16.5.

Per cent oxygen = 3.1.

These charts are dependent on the following facts:

1. When plotting per cent excess air *versus* per cent $CO_2$ in the flue gases for any fuel, a smooth curve, a characteristic of the fuel, can be drawn with Per Cent Theoretical Maximum $CO_2$ (Zero Per Cent Excess Air) as the starting point at zero per cent excess air. (See chart, Per Cent $CO_2$ *vs.* Per Cent Excess Air.)

* Assistant Test Engineer, Naval Boiler Laboratory.

CHARTS FOR THE DETERMINATION OF EXCESS AIR AND THEORETICAL OXYGEN ACCOMPANYING CARBON DIOXIDE IN FLUE GASES WHEN FIRING FUEL OILS
150
160
170
EXCESS AIR %
SCALE N°1
SCALE N°2
CO2 %
CARBON RATIO
HYDROGEN
CARBON
EXCESS AIR %

CO2 IN FLUE GASES %
OXYGEN IN FLUE GASES %
EXCESS AIR %
MAXIMUM CO2 LINES
EXAMPLE
FROM SCALES "I" OR "J"
MAXIMUM CO2 ZERO EXCESS AIR = 13.0%
FROM 12.0% CO2 FOLLOW DIAGONAL ASSOCIATED LINES AS INDICATED
EXCESS AIR = 15.5%
OXYGEN IN FLUE GASES = 2.7%

Likewise, when plotting per cent theoretical oxygen *versus* per cent $CO_2$ in the flue gases for any fuel, a smooth curve, a characteristic of the fuel, can be drawn with Per Cent Theoretical Maximum $CO_2$ as the starting point at zero per cent excess air. (See chart, Per Cent $CO_2$ *vs.* Per Cent Oxygen.)

2. Knowing the Per Cent Theoretical Maximum $CO_2$ (Zero Per Cent Excess Air) of the fuel being fired, the curve for that fuel which expresses the relation between per cent $CO_2$ in the flue gases and per cent excess air being used is readily identified; by passing vertically from the per cent $CO_2$ in flue gases to the Per cent Theoretical Maximum $CO_2$ curve of the fuel being fired and then horizontally to the excess air scale, the per cent excess air used may be determined.

3. The facts in paragraph 2 above apply also to the determination of the per cent theoretical oxygen accompanying per cent $CO_2$ in the flue gases.

With these charts the determination of Per Cent Theoretical Maximum $CO_2$ (Zero Per Cent Excess Air) by a quick method is imperative if the charts are to be of practical value, since ultimate analyses are laborious and expensive determinations.

The Per Cent Theoretical Maximum $CO_2$ (Zero Per Cent Excess Air) is a function of the carbon-hydrogen ratio $\left(\frac{C + .4\ S}{H}\right)$ in which

C = per cent carbon by weight
H = per cent hydrogen by weight
S = per cent sulphur by weight

from the ultimate analysis of the fuel. (See Scale 2 on chart.)

Empirically, the carbon-hydrogen ratio $\left(\frac{C + .4\ S}{H}\right)$ was found to be a function of the specific gravity of the fuel oil.

Since Per Cent Theoretical Maximum $CO_2$ (Zero Per Cent Excess Air) is a function of the carbon-hydrogen ratio $\left(\frac{C + .4\ S}{H}\right)$ the Per Cent Theoretical Maximum $CO_2$ (Zero Per Cent Excess Air) was expressed directly as a function of the specific gravity of the fuel oils. (See Scale 1 on chart.)

The following are examples of excess air determinations by calculation and excess air determinations from the accompanying chart (Per Cent $CO_2$ *vs.* Per Cent Excess Air), using Specific Gravity (60 degrees/60 degrees F.) of the fuel to find Maximum Theoretical $CO_2$.

| Per Cent $CO_2$ | Excess Air Per Cent by Calculation | Excess Air Per Cent by Chart, Using Specific Gravity |
|---|---|---|
| 12.1 | 37.1 | 35.5 |
| 13.6 | 22.6 | 21.5 |
| 14.3 | 10.4 | 10.0 |

The empirical relation between Per Cent Theoretical Maximum $CO_2$ (Zero Per Cent Excess Air) and Specific Gravity (60 degrees/60 degrees F.) was established from a large number of the fuel oils, of varying blends and types, received at the Naval Boiler Laboratory from 1922 to 1935. It is possible, however, that fuel oils in the future may deviate from this relationship.

# NOTES.

## INDEX TO NOTES.

THE FUTURE OF THE DESTROYER.
Engineering, January 25, 1935.

LIGHT CRUISERS.
Shipbuilding and Shipping Record, January 31, 1935.

TECHNICAL NEWS.
Translated from the Journal de la Marine Marchande, February 21, 1935.

FOUR YEARS OF SERVICE—MOTORSHIP "EUROPA."
Translated from the Journal de la Marine Marchande, February 21, 1935.

THE FRENCH LINER "NORMANDIE."
Shipbuilding and Shipping Record, January 24, 1935.

TAR OIL AS AN ENGINE FUEL.
Engineering, December 14, 1934.

RESTRICTIONS ON CIVILIAN EMPLOYMENT OF RETIRED OFFICERS OF THE NAVY.
Marine Journal, January 15, 1935.

MOLYBDENUM.
Bulletin of Arthur D. Little, Inc., Chemists, Engineers, February, 1935.

PITTING OF 18–8 IN NAVY USE.
Metal Progress, February, 1935.

FATIGUE IN MARINE ENGINES.
Engineering, February, 1935.

MARINE ENGINES FROM A SUPERINTENDENT ENGINEER'S POINT OF VIEW.
Shipbuilding and Shipping Record, January 17, 1935.

FUEL CONSUMPTION AND MAINTENANCE COSTS OF MARINE ENGINES.
The Engineer, February 22, 1935.

A DIESEL-ENGINED ANCHOR WINDLASS.
British Motorship, February, 1935.

PROTECTION AGAINST GAS BOMBARDMENT.
The Engineer, February 8, 1935.

GALVANIC CORROSION.
By the Secretary of A. S. N. E., (Comdr. C. S. Gillette, U. S. N.)

ABSTRACT OF THE "PROBLEM OF CORROSION."
Yachting, February, 1935.

ABSTRACT OF "E.M.F. BETWEEN METALS IN SEAWATER."
The Engineer (British), January 25, 1935.

DISCUSSION BY THE SECRETARY.

## THE FUTURE OF THE DESTROYER.

The philosophical Irishman who observed that "the greatest of all possible misfortunes is usually followed by a much greater," has long had his counterparts in engineering circles, where the completion of the best of all possible contrivances for a given purpose is usually—it might be said, almost invariably—followed by the production of one much better. This peculiarity has always been characteristic of warship design, and although the need for standardization, for reasons both of strategy and maintenance, has sometimes operated to retard the rate of development, and in recent years the effect of international agreements has tended in the same direction, the process has still continued; neither are there any signs that the ingenuity of the designer or constructor has yet reached its limit.

The close of the war left most of the allied nations with greatly augmented destroyer fleets, so that, despite the immediate scrapping of most of the prewar vessels and many of wartime construction, there was no need for fresh vessels of this type to be built for a number of years. Experience indicates, however, that an occasional lull in actual construction is definitely beneficial to progress, by providing designers with leisure to examine more closely into the possibilities of improvement than they are able to do when preoccupied with contract dates for delivery. As an indirect result, the progress of design is found to be less dependent than might be supposed upon the programs of the major navies; for it is precisely when orders for home requirements are least plentiful that the most strenuous efforts are made to secure contracts for the modernization of the lesser fleets, the demands of which upon the designer, not infrequently, are as extensive as their dependence upon his skill is absolute if the requirements are to be realized.

The effect has been that not once or twice, but many times in the history of steam navies, critics of the national naval policy have been in a position to show that British shipyards were producing for foreign account vessels exceeding in belligerent qualities anything then existing or projected for the service of their own flag. While it must be admitted that subsequent experience with some of these ships, when added by purchase to the British fleet, showed that their superiority in certain respects had only been achieved at the expense of a deficiency in others, there can be no question that they provided valuable data for use in the production of later designs.

Although there have been various improvements in detail, the general design of the post-war destroyers constructed for the British Navy displays few obvious points of difference from that of the later vessels of the wartime programs; so that it might almost be supposed that the stage had been reached when further advance was no longer compatible with the retention of the destroyer as a distinct type, but must involve its evolution into a new class of high-speed light cruiser. This tendency has been noticeable in recent years, in the vessels built for Continental navies, and is a factor of importance in the consideration of the two papers on destroyer design lately delivered—by a coincidence, within ten days of each other—on the Clyde and on the Tyne.

The paper read by Sir Harold E. Yarrow, Bart., before the Institution of Engineers and Shipbuilders in Scotland, on November 20, and reprinted in our issue of November 30, page 603, was primarily a record of fact, being an account of the trial performances of vessels recently completed by his firm for the Portuguese Navy. The other paper, by Mr. E. L. Champness, M.B.E., was delivered before the North-East Coast Institution of Engineers and Shipbuilders, on November 30, and, starting from a basis of present practice, developed a proposed type of steam-driven destroyer presenting a number of novel features, but possessing, at the same time, an attractive appearance of practicability. Whether any naval department would be pre-

pared, under present conditions, to make so many simultaneous experiments as Mr. Champness' Diesel-driven alternative design seemed to involve, may be open to some doubt; although it is evident that, in this case also, the details of the scheme have been subjected to careful study.

The main obstacles in the way of any fundamental experiment in destroyer design arise from the essential differences between the conditions governing large and small navies. The big naval power does not detail its latest destroyers to the performance of isolated duties, but uses them primarily as fleet units; and whether they are operating offensively or defensively, they do so in flotillas. In such an organization there is no place for a single vessel of unorthodox design; but, on the other hand, not even a front-rank naval power can afford, at the price of perhaps £250,000 apiece, to construct its experiments a flotilla at a time. Hence radical changes can only come about by a gradual process of evolution, and the frankly revolutionary proposal, however attractive its apparent merits, has little prospect of acceptance in time of peace, purely for economic reasons. In time of war the economic factor can be ignored, but, as numbers then become the first essential, the tendency is rather to repeat existing types of established quality—unless, that is, the enemy produces some unexpected weapon which can only be countered by an equivalent departure from precedent.

In the case of a minor naval power the conditions are entirely different, but the effect is still very similar. To an increasing extent, the modern destroyer of high fighting power is becoming the capital ship of the small navy. New vessels may be ordered in batches, and will probably exercise in flotillas under peaceful conditions; but in war time, the difficulty of maintaining an effective patrol of an extensive seaboard with a numerically weak force—a condition common to many of the smaller maritime nations—suggests that they would normally operate in pairs, at the most, or even as detached units, keeping in touch by wireless. In such circumstances the relative importance of each unit is such that, again, the responsible admiralty cannot afford to experiment.

Mr. Champness, in his paper, was considering mainly the requirements of the large navy, but the extension of the survey to include the case of the smaller naval power appears to strengthen still further his conclusion that, in its present form, the destroyer has reached the limit of practical compromise and that, for the best attainment of the many ends in view, future development requires a division of the duties between at least two sub-types. The larger of these might ultimately approach 2000 tons displacement, and would be designed solely for fleet duties, combining sea-keeping qualities of a high order with reliance upon the torpedo as the main offensive armament. In the other type, greater importance would attach to gun-power, and a lighter torpedo armament would suffice, the weight and space thus saved being devoted to mine-laying or mine-sweeping gear, or to depth charges. The suggestion is made in the paper, that a small autogiro should form part of the standard equipment, and doubtless such a machine would be of good use in anti-submarine operations, and on convoy duty. For mining work, however, its value is less evident, and the space which it would occupy might, perhaps, be better utilized in other ways.

The proposed design for the light type of destroyer is based upon a "standard" displacement of 1100 tons to 1200 tons, which corresponds to a deep load displacement, with all oil and feed tanks full, of about 1500 tons. This, it may be noted, is only some 120 tons less than that of the Portuguese destroyers described by Sir Harold Yarrow. It is open to debate, whether the principle of a reduction in size might not be carried farther with advantage, and an attempt made to return to the dimensions in vogue until and during the early years of the war. On an overall length of about 280 feet and a displacement of the order of 1200 tons it should be practicable, by making the fullest use of light alloys, welding, higher-duty boilers, and other

technical improvements now available, to design vessels capable of any destroyer requirement short of station-keeping with a modern battle fleet in heavy weather, and with a sustained speed at normal full power equal to the "spurt speed" of the later British wartime classes.

The present composite type combines high speed, good steaming radius, and a powerful armament in a remarkable degree, but for the purposes of the minor navy it appears that further advance in any of these particulars would be most satisfactorily accomplished by the re-introduction as a type of the light scout cruiser.—"Engineering," January 25, 1935.

---

## LIGHT CRUISERS.

The displacement of light cruisers is limited by the Washington Treaty to 10,000 tons in the light condition, that is, fully equipped but without fuel and feed water. This gives a normal displacement of about 12,000 tons and a full load displacement approaching 14,000 tons. The caliber of the guns is limited to 8 inches.

Exceptional circumstances may be taken into account and the caliber of the guns may be increased provided the displacement be kept within the prescribed limits. Such has been permitted in the design of the German cruisers of the *Deutschland* class, which mount six 11-inch guns in two triple turrets. In discussing this design, Prof. Hovgaard remarked that it might be conjectured that these ships are intended partly for service in the Baltic and partly for raidings or commerce destroying on the ocean. Evidence of the former purpose is seen in the heavy armament mounted, which is specially suitable for a ship of that size operating in narrow seas.

Apart from this special case, the usual armament consists of eight 8-inch guns. While the maximum standard displacement allowed is 10,000 tons, it is apparent, from present-day construction, that it is not always desirable to have units of this maximum size, and several well-defined types have been built recently for the British Navy to suit the particular requirements of the Board of the Admiralty. Some indication of these types may be gleaned from the incomplete figures in the accompanying table.

| | British | | | | German | French |
|---|---|---|---|---|---|---|
| | *Arethusa* Class | *Leander* Class | *York* Class | *London* Class | *Deutschland* Class | *Suffren* Class |
| Length, in ft. | ? | 555 | 575 | 633 | 609 | 607 |
| Breadth ,, | ? | 56 | 57 | 66 | — | — |
| Draught ,, | ? | 16 | 17 | 17 | — | — |
| Displacement (standard) | 5,200 | 7,000 | 8,250 | 9,730 | 10,000 | 10,000 |
| S.H.P. .. | ? | 72,000 | 80,000 | 80,000 | — | — |
| Speed in knots | ? | 32¼ | 32¼ | 32¼ | 26 | 32 |
| Guns .. | ? | 8-6 in. | 6-8 in. | 8-8 in. | 6-11 in. | 8-8 in. |
| | (building) | 4-4 in. | 4-4 in. | 4-4 in. | 8-5·9 in. | 8-3 in. |
| | ? | 4-3 pr. | 4-3 pr. | 4-3 pr. | — | — |
| | ? | pom poms, &c. | pom poms, &c. | pom poms, &c. | — | — |
| Torpedo tubes | ? | 8-21 in. | 6-21 in. | 8-21 in. | 6-19·7 in. | 6-21 in. |

In the designing of cruisers of this type, consideration must be given to three dominating features, viz.: armament, protection and speed. From the figures given for the German ships, it can be seen that speed has been sacrificed for gun power. It is possible, also, that the amount of protection which has been afforded is greater than that usually given to this type of ship. While it is manifestly impossible to give to cruisers of this class the armor protection which would be adequate to withstand the gun power of battleships with which they might well be in conflict, it is necessary that some protection be afforded. The general principle which has been propounded as being suitable of application is that an artillery ship should be so protected that it can keep up a sustained fight under average conditions with a ship of similar size and type carrying the same armament. Applying this principle as far as possible within the prescribed limitations of displacement, certain weights are arrived at which can be allocated to the various factors which complete the fighting unit. The following figures have been given for the German ship and for a British cruiser of the 10,000-ton class:—

| | *Deutschland* Tons | *Suffolk* Tons |
|---|---|---|
| Hull without armour .. .. | 3,700 | 4,400 |
| Armour .. .. .. .. | 2,700 | 2,000 |
| Auxiliary machinery .. .. | 480 | 400 |
| Equipment .. .. .. | 430 | 430 |
| Main machinery .. .. .. | 1,150 | 1,930 |
| Armament.. .. .. .. | 1,700 | 1,000 |
| Light displacement .. .. | 10,160 | 10,160 |

From an examination of the above, it is clear that seaworthiness and speed have been the main consideration in the British design, while protection and gun power are the dominating features of the German ship.

With regard to speed, the power in the latest British 10,000-ton cruisers has been raised to 90,000 S.H.P., which falls far short of the 120,000 S.H.P. given to the French vessel *Tourville*, which is said to have very little protection. In the later French vessels, of the *Suffren* class, the power has been reduced to 90,000 S.H.P., giving a speed of about 32 knots. The Italian *Trieste* class is credited with a speed of 36 knots, while the Japanese *Nachi* class is said to have a speed of 33 knots and the battery comprises ten 8-inch guns.

In this type of vessel, perhaps more than in any other, the best compromise between the various "desirables" must be effected. While it is necessary to afford adequate gun power, protection and speed, the limitation of displacement imposes restrictions in each of these directions. Perhaps the best all-round design is that of our British ships, which have good sea-going qualities and possess reasonably good offensive and defensive qualities and high speeds.—"Shipbuilding and Shipping Record," January 31, 1935.

---

## TECHNICAL NEWS.

The Japanese merchant fleet has recently been augmented by new speedy tankers: the *Toa-Maru* and the *Kyokuto-Maru*, built by the Kawaski Dockyard Co., to the order of the Jino Shoji Kaisha Co., Ltd., designed for regular traffic between Japan and the United States. While the speed of the world's tankers of recent date rarely exceeds 12 to 13 knots, these two

new units of the Japanese have been built for a speed of 18½ knots, and on the trial of the *Toa-Maru* she ran 19 knots.

It is pretty certain that military considerations were not strangers to these characteristics.

The principal dimesions are as follows:

| | |
|---|---|
| Length, P.P., feet | 500 |
| Beam, feet and inches | 64–11⅜ |
| Depth, feet and inches | 36–10⅜ |
| Draft, feet | 29 |
| Displacement, tons | 13,500 |
| Gross tonnage, tons | 9,890 |
| Net tonnage, tons | 5,740 |
| Designed horsepower | 8,000 |
| Maximum horsepower | 8,590 |

In the steel construction these ships are sensibly different from the current practice in tankers; instead of having a longitudinal central partition, there are two partitions running fore and aft of the tanks and extending upwards to upper deck.

The transverse partitions are decreased so well that the partition is limited to one for the central tanks, and falls athwart the middle of one lateral compartment.

There are also 20 tanks. In order to facilitate the transport of different products of petroleum, cofferdams are situated along the length of tank space dividing the tanks into two groups, one fore and one aft. The summer tanks have been eliminated.

This system of construction is particularly advantageous for voyages when running light, the central tanks only being used. Some special gasoline tanks are deposed well forward laterally.

The pump room is placed in the center and its position is between two continued lateral partitions and two transverse partitions. There are four groups of pumps, each having an output of 79,251 gallons per hour, one hold pump, 10,567 gallons, one hold and ballast pump 21,134 gallons and a Sirocco blower of 7063 cubic foot capacity.

All the pumps are Worthington steam drive; forward there is one steam pump of 10,567 gallons installed for gasoline service.

Coils for heating are installed in the bottom of all oil tanks at a ratio of heating surface of 0.484 square feet per ton of oil. The steam that circulates in the coils is produced by an auxiliary boiler at 100 pounds pressure and the exhaust drains into an observation tank placed in the fireroom.

Forward of the ship is provided a hold for cargo, also one in between decks fore and aft; four steam winches are provided for handling cargo. The windlass and capstan are steam driven. The steering gear is of an electric hydraulic type, operated by an electric motor of 20 horsepower governed by a telemotor. The main propelling machinery is a Diesel engine of the Kawasaki-M.A.N. double acting, two cycle, mechanical injection type, having eight cylinders 27.3 diameter, stroke 46.8 inches, built by the Kawasaki Dockyard Company.

The designed horsepower is 8000 at 110 R.P.M., but on the official trials of the *Toa-Maru* 8591 H.P. was developed and the speed attained was 19.1 knots, which constitutes a phenomenal record for ships of this class.

Electric energy for the auxiliaries is furnished by three Diesel dynamos, Kawasaki-M.A.N., 4 cycle, single acting, mechanical injection, having seven cylinders 11.11 diameter by 16.38 stroke.

These Diesel motors developed 451 H.P. at 375 R.P.M., the generators have a capacity of 295 kilowatts, 225 volts, and one auxiliary dynamo of 40 H.P. at 450 R.P.M.

The steam necessary for heating the tanks, feeding the pump, divers auxiliaries and internal arrangements, etc., is produced by two auxiliary boilers, each 23.4 square feet heating surface, and one exhaust gas boiler, having 31 square feet heating surface, all three being rated at 177.5 pounds pressure.

The circulating air for the principal motors is produced by an electric turbo-blower built by the Mitsubishi Hoke Works. This blower capacity is 37,080 cubic feet. The operation is by two electric motors of 350 kilowatts, at 2580 R.P.M., one of these motors serving as a spare.

The compressed air used for maneuvering is 426 pounds pressure and is supplied by two three-stage compressors, attached to the generator group. Each compressor has a capacity of 14,125 cubic feet.

In the course of these trials the *Toa-Maru* consumption was 0.384 pounds per brake horsepower hour, 8120 brake horsepower and the indicated horsepower 8811, the displacement being 19,200 tons, and the draft 27 feet 8½ inches.—Translated from the "Journal de la Marine Marchande," 21 Feb. 1935.

---

## FOUR YEARS OF SERVICE—MOTORSHIP *EUROPA*.

The Journal of the Merchant Marine four years ago gave a description of the two motorships *America* and *Europa*, being the first engines built by Burmeister and Wain of two cycle, double acting type with mechanical injection. These ships owned by the East Asiatic Company of Copenhagen, are ostensibly engaged in service between this port and the Pacific Coast of the United States.

The *Europa* made her maiden trip May 1931, hence she has been engaged continually for nearly four years. In the course of her first fourteen complete trips she has covered some 289,000 miles, 273,600 of which were at maximum speed. The cruising speed was 14.6 knots, one voyage run at 15.26 knots and the mean run was 13.68 knots.

The mean revolutions for this period was 92.7 per minute.

The propulsive machinery is a six cylinder engine, 24.18-inch bore, with a stroke of 54.6 inches, were designed to develop 6000 horsepower at 95 R.P.M.

It will be noted that the mean number of revolutions for the fourteen trips is very near the designed revolutions. Five trips of the fourteen gave a mean of 93 R.P.M., and the first run was made 95.6 R.P.M.

The fuel consumption gradually decreased from an average of 24.26 tons to approximately 21 tons. The mean of the 14 trips are 21.25 tons. The consumption per indicated horsepower per hour changed from .311 to .281 pounds, giving a mean for 14 voyages of .286.

The lubricating oil consumption varied considerably from one voyage to the other. The mean consumption for the fourteen trips was 37 pounds per day for the working parts and the consumption of oil for the cylinders varied from 99.2 to 105.82 pounds per day, and on this basis allowing 4.4 pounds for each auxiliary Diesel gives about 116.8 pounds per day.

Port weight of the *Europa* is 12,000 tons.—Translated from the "Journal de la Marine Marchande," 21 Feb. 1935.

## THE FRENCH LINER *NORMANDIE*.

### A Visit to the World's Largest Electrically-Propelled Ship and the First Liner Over 1000 Feet in Length to Go into Commission.

By A. C. Hardy, B.Sc. F.R.G.S., A.M.I.N.A.

Some ships can be appreciated, and visualized very correctly from constructional photographs and plans; others require a personal visit in order that a true realization may be obtained of the principal features of construction of hull and machinery.

The French Line super-liner *Normandie*, now rapidly completing at the yard of the Chantier & Ateliers de St. Nazaire-Penhoët, belongs strictly to neither category, for a study of her plans gives only a very indifferent appreciation of the multitude of constructional features of this monster ship, while even to visit her at her present stage of construction leaves the most "hard-bitten" shipping man marvelling at the possibilities of modern naval construction, when neither building time nor money spent are matters of prime consideration.

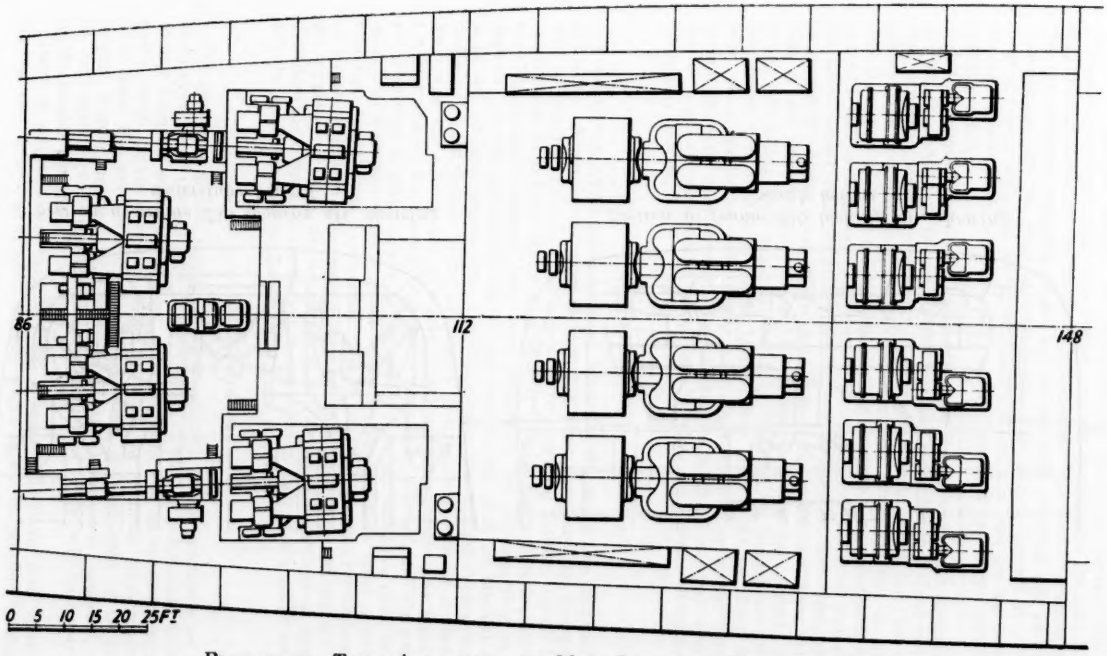
It is true that to be appreciated in even the most cursory way, the *Normandie* must be visited, and after that a detailed study made of her plans. Even so, once round hull and machinery space is of little or no avail. At least two days should be spent literally tramping from deck to deck, from one vast public room to another, from arrays of boiler rooms to the enormous power stations, pipes and engine rooms, from huge motors to gigantic switchboards. These phrases may sound a trifle extravagant, but to one who, thanks to the courtesy of the London director of the French Line, M. Pierre de Malglaive, who is largely responsible for the outstanding features of the ship, has just had an opportunity of inspecting her, the words are, indeed, no exaggeration whatever, but a further appreciation of a step in ship construction which will surely go down to history as one of the boldest ever made.

It is felt, therefore, that it is of interest at this time when the *Normandie* is virtually complete as far as the steel work in her hull and the details of her machinery are concerned, to place on permanent record a few impressions of the ship in her final constructional stages.

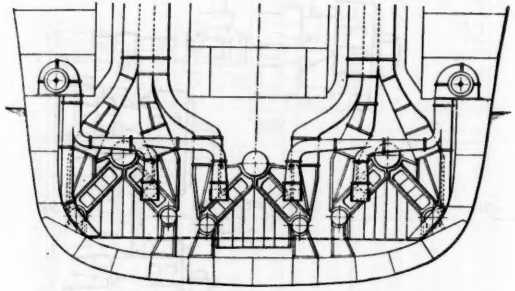
The ship is alongside the fitting-out wharf of the Penhoët shipyard. At the time of my visit her masts and three funnels were in position; work was being well pressed forward to put the finishing touches to her gigantic machinery, while the beginning of woodwork and interior decorations on the large public rooms and cabins was also being pressed forward with the utmost despatch. Indeed, hurry is certainly necessary, for the sea trials are being held towards the end of April and the ship is scheduled to sail on her maiden voyage from Havre to New York on May 28.

As far as the hull is concerned, the ship presents many unique features. As will be recalled from data published at the time of the launch, this is constructed on the Yourkevitch principle. It has an enormous curved raking bow, counter stern, three large funnels of equal height, a navigating bridge which is so far forward that it appears to be almost part of the "forecastle," a curved whaleback forward merging into an enormous steel breakwater structure, which it is expected will keep the bow end of the ship dry even when she is pushing at full speed into the heaviest of Atlantic storms.

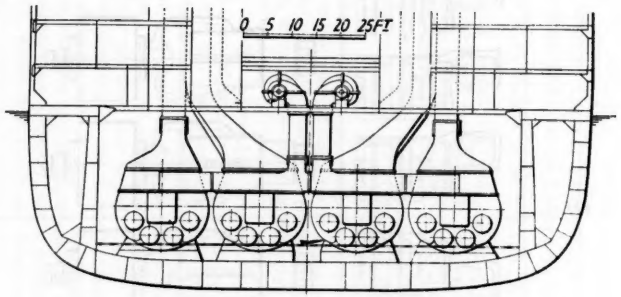
All the mooring gear of the vessel is under cover, the "forecastle" being really no forecastle at all but simply a deck, covered over by a turtle back, on which powerful electric capstans are arranged. The same arrangement applies to the aft end, which is likewise covered in by a somewhat lighter




PLAN OF THE TURBO-ALTERNATOR AND MAIN PROPULSION MOTOR ROOMS OF THE "NORMANDIE." ALSO SHOWN ARE THE SIX DIRECT-CURRENT AUXILIARY GENERATORS AT THE FORWARD END.



*Section at frame 236 looking aft, showing water-tube boilers*




*Section at frame 206 looking aft, showing Scotch boilers*

structure, flat in nature. It is interesting here to remark that the *Normandie's* mooring gear has been in position since before the launch, and that during and after the launch it was actually operated by current from the two auxiliary stand-by diesels on the top deck. During her period of construction, she has been of considerable assistance to herself in moving back and forth along the fitting-out basin wall and also into the big entrance to the Penhoët basin which is alternatively locks and dry docks, according to requirements.

A few items of interest in connection with the passenger accommodation are worth mentioning in view of the fact that work for their final completion is now in active preparation. We may take first, in this case, the main dining saloon, which is a magnificent apartment some 300 feet in length and about two-thirds of the beam of the ship in width. Its cubic dimensions are such that, without any exaggeration, an average cross-channel ship could be safely placed inside. Glass panelling is to be used on both sides, and it is an interior dining room in the sense that it does not extend from side to side of the ship, because—as M. Pierre de Malglaive has argued—when people are eating they are not necessarily interested in looking out of the port-holes, even if it is physically possible for them to do so. Lest, however, there should be any danger of the air in this enormous internal restaurant being contaminated, the whole is changed at frequent intervals by a large air-conditioning plant supplied by the Carrier Engineering Company, London.

### VENTILATION.

Ventilation has been made a special feature of the whole ship, and without going into details here it may be said that when completed the *Normandie* will be found to have in this connection very unusual features which have not hitherto been fitted on existing vessels. British sub-contractors, namely the Thermotank company, have been responsible for the supplying of the majority of this equipment, and it may be said that it is all internal, that is to say, all fans, heaters, etc., are placed inside the topmost superstructure and air for distribution to the passengers' places below is swept in through louvres in the side of this structure. Such an arrangement was fitted for the first time on the French Line's cabin class liner *Champlain*. The principal advantage is that it gives an absolutely clear top deck, *i.e.*, clear in the sense that there are no ugly cowls or vents taking up deck space otherwise extremely useful from a passenger point of view for games or promenading or sitting. The ventilation system requires in all 160 fans and motors and the trunking to carry the air totals in all about 45 kilometers in length. Thermostatic control to ventilation is employed in each of the public rooms and the air is changed no less than 20 times per hour.

### PUBLIC ROOMS.

The system of divided uptakes has been adopted, giving practically an uninterrupted vista through the public rooms. There is a full-sized cinema theater complete with sloping floor, a large chapel and an enormous winter garden with curved fore-end in the front of the immense superstructure. This latter, like most of the other public rooms, is remarkable for its great height. Throughout, the ship's interior decoration, when it is completed, will be such that in every possible case the illusion of height will be preserved to the utmost advantage.

There is an enromous café bar, and a large grill room with windows opening out on to a grill-room terrace, where it will be possible by means

of carefully placed screens for passengers, in fine weather, to take their meals out in the open in true Continental style. It is no exaggeration to say that every possible use has been made of glass. Special safety glass is fitted to all the superstructure windows and exhaustive tests have been carried out on this glass to ascertain that it is able to stand up without breaking to the hardest blows from transatlantic seas that it is likely to encounter.

Of the three enormous funnels, two are arranged to take the furnace gases from the 29 Penhoët water-tube and four Scotch boilers, but so enormous are the casings surrounding the funnels that No. 1 funnel can be used at sun deck level for a large children's lounge and Punch and Judy show, while No. 3 funnel houses a large dog "compartment de luxe," comprising a green and white tiled floor, a large drinking fountain in the center and two tiers of kennels. In order to secure lightness in the upper structure wherever possible, the outer plating of all the funnels is galvanized. They are also flush riveted with internal butt straps, so that the funnels themselves will present rather a smoother appearance than usual. Possibly streamlining, which has been carried to a very extreme point on this ship, may have a great deal to do with it. There are two swimming pools, one of outstanding magnificence in the first-class and the other in the tourist-class.

Precautions have been taken to avoid the possibility of any outbreak of fire, and to control it if there is. All the indicators are centralized in a special station above and abaft the main dining saloon. By this means the ship, from a fire-detecting point of view, is divided into three sections vertically and two groups horizontally, one officer is told off specially for fire-detecting duties, and day and night someone will be on duty in this detecting station. A large force of firemen will also be carried, as well as a large equipment of gas extinguishing apparatus.

### CABINS.

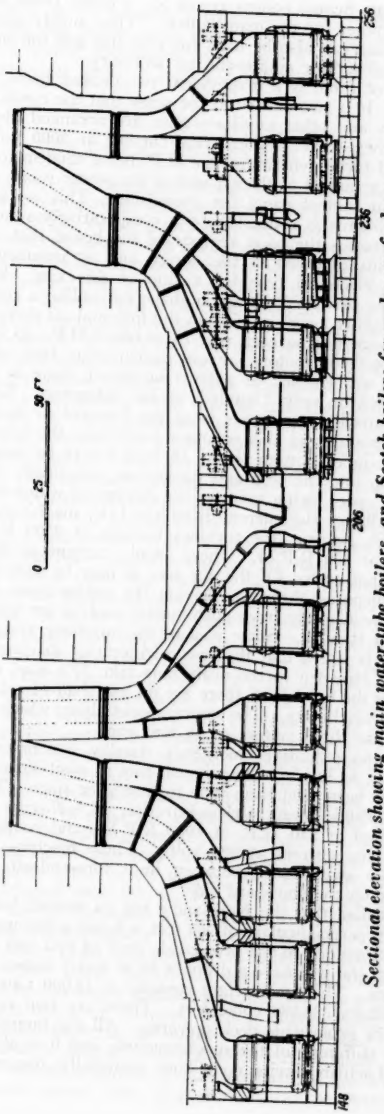
The main promenade deck is long, wide and deep, panelled in oak throughout and completely glass encased. In fact, the more one inspects this vessel with her luxurious cabins—practically every one different and everyone having a bath and toilet or shower and toilet—the huge dining saloon and auxiliary dining saloons, cafés, baths, smoking rooms, theater, chapel, winter garden, suites de luxe with their own sitting room and private deck space the more one is compelled to marvel at the way the naval architect can lay out a ship structure today.

Considerable ingenuity has been displayed in the arrangement of the cabins, two-thirds of them being outside cabins, this being an exceptionally high proportion for a vessel of this class.

### PROPELLING MACHINERY.

Amazing as all these features are, however, a visit to the engine room and boiler rooms is none the less important, for here power-station practice is brought to sea to the tune of some 160,000 H.P. output. The power plant for main and auxiliary purposes, as the sketches reproduced herewith show, is broadly divisible into three portions—the boiler rooms, the main power room and the motor room, this latter also containing the distribution panel for the high-tension machinery as well as the refrigerating machinery and plant for conditioning the air in the dining saloon.

The main boiler rooms contain, as has been mentioned above, 29 water-tube boilers of special Penhoët design. These supply to the turbines superheated steam at 325 degrees C. temperature at the admission valve and at 28 Kg.




*Sectional elevation showing main water-tube boilers, and Scotch boilers for make-up feed purposes*

pressure. The four Scotch boilers are in No. 3 boiler room and are used for make-up feed purposes for the main boilers. They supply saturated steam at 10 Kg. pressure and can also be used for port use and for running a certain part of the D.C. generator equipment, as necessary.

The main power room is a magnificent two-decked space, some 36 frame spaces in length. It is two-decked in the sense that the condensers, enormous circulating pumps and other auxiliary gear are arranged directly under the turbines which they serve. Alternating current at 5000 volts is generated in four compound turbo-generators, the H.P. being tandem to the L.P. cylinders. These are arranged at the aft end of the power room, and above them again is the main control panel for propulsion. This, so far as the space occupied by the boards is concerned, is a comparatively simple affair. It is only when one studies the back regions of the board that one realizes the enormous problems involved in the design and arrangement of propulsion equipment of an electrical type for a ship of this size. Facing the main control boards are two small boxes in shape not unlike a covered-in musical organ, and three short levers moving in the fore-and-aft direction are all that is required for maneuvering each pair of 40,000 S.H.P., 30,100 Kw., 3-phase synchronized propulsion motors. From maneuvering tests of a minor character which one was enabled to witness on board, there is little doubt that the *Normandie* wil be very "handy" on her telegraph. The main switchboard for D.C. auxiliary purposes is at the forward or boiler-room end of the main power room, and this occupies practically the whole width of the ship between the inner bottom shell. It should here be mentioned that this is carried well up into the ship and throughout practically the whole length of the machinery space, being used for the storage of water ballast, etc. This main board distributes the current from six D.C. machines, each driven by a turbine through gearing, the turbines turning at 2500 R.P.M., while the generators turn at 530 R.P.M. These supply current at 225 volts and are of 2200 Kw. output each. Of the six sets, it may be said two are required for hotel load purposes, three for driving the engine-room auxiliaries, most of which latter incidentally have push-button control for stopping and starting, and one is a standby. Some idea of the auxiliary requirements may be recalled when it is stated that the two refrigerating machines take 77.5 Kw. each and the 20 Howden forced-draft fans take 57.5 Kw. each and turn at 620 R.P.M. For the hotel load, there are no less than 44 cables and 36 cables for the auxiliary machinery. The steering gear alone, which is of the electric hydraulic type, has three motors of 48 Kw. each.

There is also an extensive emergency standby system on the promenade deck itself. This, as has been mentioned, was in position when the ship was launched and has been used from time to time ever since. The set comprises two four-cycle, single-acting airless-injection M.A.N.-type Diesels built in France, each rated at 240 H.P. at 1000 R.P.M., and coupled to a 160-Kw. generator supplying current at 220 volts. These machines are arranged in tandem with the switchboard between in a fore-and-aft direction on the promenade deck on the starboard side.

It may be recalled that the Normandie has an overall length of 1027 feet, a length between perpendiculars of 963 feet, a beam at the main deck of 117.75 feet, and a depth molded to the promenade deck of 91.3 feet. It is stated that in load condition she will have a draught of 36 feet 7 inches, and will displace some 67,500 tons. The dead weight capacity is 12,000 tons and the capacity of her fuel bunkers 388,980 cubic feet. There are two expansion joints in the hull from the promenade deck upwards. All the funnel casings are used for the general stiffening of the superstructure, and it is also considered that the Welin-McLachlan davits contribute materially towards the stiffening

of the ship. There are 11 watertight bulkheads; the double hull extends, as mentioned, through the engine room space; the decks are numbered A to H, but F deck is the lowest continuous deck, while A deck is the strength deck and also the promenade deck.—"Shipbuilding and Shipping Record," January 24, 1935.

## TAR OIL AS AN ENGINE FUEL.

One of the most serious problems facing the belligerents on both sides in the great war was to insure an adequate supply of liquid fuel for the various branches of the fighting services, and with the growth of the mechanization of land forces, together with the probable enormous increase in air activity, it is hardly too much to say that in any future wars between the great powers, the countries possessing the greatest resources of such fuels are likely to prove the victors. Even in peace time, an abundant supply of cheap liquid fuel is an important factor in prosperity, and there can be little doubt that the large preponderance of the American automobile industry over those of the European States is as much due to the lower price of petrol as to the greater size of the home market. These considerations have led various European countries to consider from time to time the possibility of insuring an adequate supply of home-produced fuel suitable for transport purposes. In the case of this country, the problem is greatly increased in complexity by the entire dependence of the Navy on liquid fuel and the tendency to substitute oil for coal in many merchant vessels. The resulting demand for oil fuel is so enormous that there appears to be no possibility of meeting more than a fraction of it by any known method of abstracting oil from coal, and this has led certain authorities to deplore the abandonment of coal in favor of oil burning in the Navy and elsewhere. The fact is, however, that this policy has been forced upon the country by both economic and technical considerations, and the likelihood of a reversion to coal is exceedingly remote. The fact that there is no prospect of meeting more than a relatively small proportion of our liquid fuel requirements from home sources is no reason for failing to make the best of the situation, but merely serves to intensify the necessity for raising the production to a point at which it would at least cover the most essential requirements in time of war, and it may be presumed that this is the broad policy of the Government, as instanced by their interest in the development of the hydrogenation process.

Before considering the present position of home-produced liquid fuels, it may be recalled that many efforts have been made, both here and on the Continent, to utilize native solid fuels to better advantage, the aim of those interested having been to raise the efficiency of the plant utilizing the fuel to a point at which they offer an attractive alternative on a strictly economic basis to those operating on imported oils. The protagonists of such proposals have been particularly active in the field of road transport. It may be taken as definitely established that the practice of burning the solid fuel under boilers, as in the case of the steam lorry, has proved generally uneconomical, except in quite exceptional cases, but it would be unfair to pass a similar verdict on either compressed coal-gas or on mobile-producer plants. In all three cases, the chief factor which militates against success is that the economies secured by burning a cheaper fuel are offset to a greater or lesser extent by increased operating charges, such as higher wage bills or bigger maintenance charges, which may be coupled with a decreased radius of action. Very promising results, already referred to in our columns, have, however, been secured with recent examples of both compressed gas and producer-gas plants, and it would appear that, if prejudices can be overcome, either or

both of these methods of utilizing native fuel may have a not-unimportant future.

The home-produced liquid fuels at present on the market are almost exclusively obtained from gas works and coke-oven plants and consist mainly of benzole and tar oils. Some 17,670,000 tons of coal are carbonized yearly, yielding 214,762,000 tons of tar, of which 25 to 30 per cent is possibly available for fuel in one or other of the two forms. The production of oil by the hydrogenation process has not yet commenced, though it is stated to be on the point of doing so. Such production has, however, already reached considerable proportions in the United States and Germany, and it is ultimately likely to be the chief source of home-produced liquid fuel in this country. Until a few years ago, the vast majority of transport engines were designed to run on petrol, and while these were quite suitable for utilizing benzole, they could not be used for tar oil. The introduction of the high-speed airless-injection engine did not appreciably affect the situation, as the use of tar oils in such engines presented very serious difficulties. Recently, however, very promising results with this fuel have been obtained with the Hesselman engine in Germany, and a considerable amount of work has been carried out in this country on the development of special vaporizers, which enable tar oil to be employed in petrol engines. The Hesselman engine was recently described in our columns, and it may be recalled that while it resembles a compression-ignition engine in that the fuel is injected through nozzles by means of a pump, the compression ratio is approximately the same as that of a petrol engine and is, therefore, too low to cause self-ignition. Actually, the fuel is ignited by a sparking plug.

The development of special vaporizers for tar oils is largely due to the work initiated by Mr. J. D. Smith, of the Belfast Corporation Gas Department, and has lately been discussed in a Report on the use of coal-tar oils in internal-combustion engines, presented on November 6 and 7 at the Autumn Research Meeting of the Institution of Gas Engineers. The essential condition to enable tar-oil fuels to be employed in spark ignition engines is that the fuel must be heated at least to a temperature sufficiently high to insure that enough of it is evaporated to form an explosive mixture in the cylinder and also sufficiently high to insure that condensation cannot occur in the induction pipe. This condition can be insured by utilizing the exhaust gases to heat the induction system, but if the engine alterations are confined to the latter, the weight of fuel and air drawn into the cylinder will be reduced, decreasing the volumetric efficiency, and the power output. In addition, fuels which are difficult to volatilize condense readily on the walls of the cylinders, the low temperature of the condensate and its comparatively poor access to oxygen resulting in incomplete combustion and in carbon formation. There is thus a further loss in efficiency, with the likelihood of rapid contamination of the crankcase oil. These objections can be reduced by keeping the cooling water at as high a temperature as possible. So far as we know, no attempt has been made to utilize evaporative cooling in this connection, and an investigation on these lines would be of interest. High wall temperatures naturally result in a further fall in volumetric efficiency, but this can be largely off-set by increasing the compression ratio. The extent to which this can be effected in a standard engine is governed by the ability of the components to withstand the increased stresses, and it therefore follows that to utilize tar-oil fuels to the greatest advantage it would be necessary to design a special engine, rather than to adapt an existing model.

Turning now to the actual systems in use, a number of special vaporizing systems have been developed, the majority involving two carburetors. One of these is used for starting up, idling, and running at low speed on petrol,

and the other, of larger size, for normal running on tar-oil fuel. A special manifold is fitted, in which the exhaust gases are passed round the induction pipe, the design embodying highly heated impact surfaces for the oil leaving the carburetor, with the remainder of the induction system heated to a more moderate temperature. The change-over from petrol to tar-oil fuel is frequently effected automatically by a thermostatic arrangement. While some users of vehicles operating on the fuel appear to have had little or no trouble over long periods, the results on the whole appear to have been disappointing. It is probable that the more successful users have been fortunate in the particular fuels and engines selected for their experiments, and the possibility cannot be ruled out that a considerable measure of success might be achieved with a standardized tar-oil fuel employed in a specially-designed engine. As stated, however, the development of the latter would be costly, and as the standardization of the fuel would be still more so, the prospects of this particular development are anything but bright. The actual position at the present time is summed up in the report referred to in the statement that the Belfast Omnibus Company, after using some 72,000 gallons of the fuel in 28 omnibuses over a period of nearly two years, and having thus obtained extensive experience, have discontinued its use. The London General Omnibus Company carried out some experimental work on the same lines, but abandoned it after a relatively short trial, and of the other municipal or private users who have investigated the possibilities, only a few of the more enthusiastic are still employing the fuel.

It has already been mentioned that the use of the fuel in airless-injection engines presents serious difficulties, but it is not unlikely that, if tar-oil fuel is ever utilized to any considerable extent, it will be in such engines rather than in those of the spark-ignition type. The chief difficulty in airless-injection engines arises from the high spontaneous ignition temperature of the fuel, this being in the neighborhood of 500 degrees C., as against some 250 degrees C. for a normal oil. Two suggestions have been put forward for lowering this temperature, the first being by the addition of a pro-knock material, and the second by the use of a catalyst chamber in front of the combustion chamber. Suitable pro-knock materials are costly and would have to be used in rather large quantities, so that the second suggestion appears at the moment to be the more promising. It is at present being investigated commercially by Gewerbschaft Matthias Stinnes in co-operation with the Büssing N.A.G., of Brunswick. Road tests are about to be undertaken, and the results will be awaited with considerable interest. In conclusion, it may be mentioned that the fuel can be mixed with ordinary Diesel fuel oil with satisfactory results so long as the proportion is kept relatively low, the only objection to this procedure being that the vehicle on which it was employed would be subjected to the same taxation as one employing Diesel oil only, so that the gain in economy would be small.—"Engineering," December 14, 1934.

---

## RESTRICTIONS ON CIVILIAN EMPLOYMENT OF RETIRED OFFICERS OF THE NAVY.

The preponderance of naval work in civil activities from which retired naval officers are debarred by law places a severe handicap upon the junior grades who are retired on minimum stipends.—Efforts are under way to modify the drastic provisions which are keeping many able ex-naval officers from supplementing their incomes by offering their experience and training to civilian employers.

A clause in the Naval Appropriation Act of 1896 forbids retired naval officers to engage in civilian employment where there exist contractural relations with the Navy Department. In view of present conditions, where the major portion of our industries are always in connection with governmental activities—with special emphasis upon naval construction—serious restrictions are necessarily placed upon the employment of the talent of retired naval officers who are thus disbarred from engaging in civilian work where their experience and training would prove of national advantage. This works an unnecessary hardship, especially upon the junior grades, where the maximum retirement pay is not sufficient to offset the loss of income that might be derived from civilian employment. As the matter now stands, it is necessary for a retired naval officer to resign from the Navy to accept a civilian assignment where there is contact with naval works, thus sacrificing his retirement pay and subjecting himself to the vagaries of the labor market. The retirement pay of the junior grades is too small to compensate for the restricted opportunities at present available, because of the preponderant activity in naval construction which is the kind of work he best understands and for which civilian employers might engage his services.

The Navy has, at last, a system of promotion, for line Officers, which will insure a uniform flow from the lowest to the highest ranks and at the same time provide highly efficient Officers in each rank but when this system is in full operation a great many Officers will have to be eliminated as it is evident that many more Officers are required in the lower ranks than in the higher.

The young men who start in each year as Ensigns cannot *all* expect to become Admirals, but the normal attrition (due to death, disability, resignation or dismissal) is not sufficient to reduce the number of Ensigns who enter to the number of Admirals who may be required thirty to thirty-five years later. In order to rectify this a system of promotion by selection and forced retirement is used. Under this system if a Lieutenant junior grade is not selected for and promoted to the grade of Lieutenant by the time he has served seven years from the date of his original commission as an Ensign he is retired. A Lieutenant must be promoted to the grade of Lieutenant Commander before the completion of fourteen years' service or be retired, etc. The service limits for the other grades being Lieutenant Commander, twenty-one year; Commander, twenty-eight years, and for Captain, thirty-five years.

This system is satisfactory enough for the purpose of maintaining the flow of promotion in the active service at a fairly uniform rate and will insure a high type of Officer in all grades but the ones who are eliminated in the process will find themselves in a very embarrassing predicament. Most of them have families and must go to work to eke out a living, but under the present laws they are debarred from almost all employment where their experience and training could be used to advantage. This is a situation which is causing considerable concern and one which should be rectified without further delay.

At the present time officers of the Navy are placed on the retired or the inactive list for one of the following reasons:

1st—Every officer who reaches the statutory age limit of 64 years is retired.

2nd—Officers who are found physically unfit for further service, due to their service, are placed on the retired list.

3rd.—Officers who have not been selected for promotion, after a given number of years' service, are placed on the inactive list.

4th—Officers may, with the approval of the Secretary of the Navy, voluntarily retire after 30 years' service and officers have a right to be retired at their own request after 40 years' service.

The law covering the employment of retired officers applies to all these classes and greatly restricts their activities in civil life.

The Naval Appropriation Act, approved June 10th, 1896, contained the following provision:

"That hereafter no payment shall be made from the appropriations made by Congress to any officer in the Navy or Marine Corps on the active or retired list while such officer is employed, after June 30, 1897, by any person or company furnishing naval supplies or war material to the Government; and such employment is hereby made unlawful after said date."

For years efforts have been made to have this piece of legislation changed as it only applies to Officers of the Navy and Marine Corps and places these Officers at a special disadvantage. Of course, so far as the law applies to Officers on the active list it is not to be questioned, but in the case of retired officers it would be to the advantage of both the Navy and the company furnishing "Naval Supplies" if the latter could utilize the service of these Officers. The Navy would know that there was some one in the company's organization who understood the needs and requirements of the Navy and the company would frequently be saved much trouble and expense for the same reason.

There is reason to hope that the present Congress will modify this legislation, but so many years have elapsed that there is no assurance of it. However, if a clear understanding of the discrimination under which these Officers suffer is gained, there is no doubt about Congress giving the proper answer.

In contrast to this the retired officers of the Army are governed by the following:

"That no payment shall be made from appropriations made by Congress to any officer on the retired list of the Army who for himself or others engages in the selling, contracting for sale of, negotiating for sale of, or furnishing to the Army or War Department any supplies, materials, equipment, lands, buildings, vessels or munitions."

The provision in the Naval Appropriation Act of 1896 is so worded as to require a very broad interpretation and it has made it practically impossible for a retired naval officer to hold any position in an important business as it is evident that "naval supplies and war material" now include almost every article used commercially. While the retired army officer is free so long as he does not "sell" to the Army or the War Department, the retired naval officer is precluded from being associated with anyone who sells to the Government.

In order to correct this condition the Navy Department has had a bill introduced (H. R. 6789) which amends the Act of 1896 by striking out the words "or retired" so that the law would then apply only to officers on the active list. This bill has been referred to the Naval Affairs Committee, but no hearings have been held. When this bill is acted upon it will help matters immensely even if it is amended so as to read more like the Army bill.

It can be readily understood that the Navy Department is never in a position to press the bill very actively, as it always has much important legislation concerning the active Navy to handle and seldom finds itself free till Congress is ready to adjourn. However, some immediate action is necesasry if the increasing number of comparatively young retired officers are to be permitted to use their talents and make a living.

It is evident that a great many more officers are required in the lower grades than in the upper grades and the theory is that each class that graduates will go up every seven years until it reaches the grade of Rear Admiral, but necessarily the number in the class must decrease as it reaches each new grade. In order to accomplish this a "Selection Board" selects the best of those eligible for promotion to the next higher grade. In deciding on "the best" many things are taken into consideration, and because an officer is passed over is no proof that he is not a very good officer. For instance, all of the Commanders, Captains and Rear Admirals now on the list

were selected for their promotion and must be good, yet only one out of each two Commanders can expect to become a Captain and only one out of each four Captains can expect to become an Admiral, and in the course of time the ones who fail to be selected for promotion will be placed on the retired list. The retirement time is so fixed that each officer has several chances for selection before different boards, but in the end if he has not been selected he must retire when his service in grade is completed.

This adding of retired officers may, at first, seem expensive, but in reality it is not, for if all were retained it would not be long before the whole upper half of the list would be receiving the maximum possible pay (after 30 years' service) and the cost would be greater than it is now because no one gets maximum pay until he is well along in the Captains' list.

Now these officers, having been placed on the retired list, find it necessary to find some employment to augment their incomes. They have had a long course of education and training in the Navy and are prone to be more useful in technical fields than in any of the other fields of activity, yet under the present law they are debarred from any employment in the fields where they would be most useful. The situation which will arise when the Lieutenants and Junior Lieutenants begin to retire will be very acute and the Navy Department has recognized this and it is hoped will include a clause in the Naval Appropriation Act to be submitted to the present Congress, which will correct the condition, but it is not at all certain that it will be well or favorably received by Congress. The idea is often expressed that these officers are well paid for doing nothing. The answer to this is that they have devoted years to a highly competitive and very unremunerative occupation and they form a reserve for the Navy of very great value.—"Marine Journal," 15 February, 1935.

---

## MOLYBDENUM.

The largest mine in Colorado, at least in terms of ore removed daily, is operated exclusively for molybdenum, a metal that many of us are still accustomed to consider rather rare and of relatively little importance. This metal somewhat resembles tungsten but has only about half its weight, and until recently possessed much less than half its industrial importance. Yet, if its startling increases in sales and production are long continued, the economic positions of these two metals may soon be reversed; already molybdenum has taken the lead in certain categories. This shift is of especial interest to Americans, for the United States produces some four-fifths of the world's molybdenum, and although American tungsten production has been increasing, the great bulk of our normal consumption of tungsten is imported from uncertain and somewhat depleted Asiatic sources. Even in normal times tungsten is subject to erratic price-changes which contrast with the stable and declining prices of molybdenum.

Near Leadville, Colorado, exists by far the world's largest known deposit of molybdenum. The Climax Molybdenum Company operated this briefly near the end of the War and then stopped operations for lack of peace-time markets. Instead of liquidating, however, it began a program of metallurgical research which by 1924 had established sufficient new uses for molybdenum to justify resumption of operations and which, continuing, has contributed toward molybdenum's almost steadily expanding demand. 1933 American production, which exceeded the previous high by almost 40 per cent, was in turn exceeded last year by almost 70 per cent.

Largest use of molybdenum by far is for alloying with iron and steel. Its applications in this field are exceedingly diverse. Although certain alloy

steels contain molybdenum as their principal alloy element, a much larger use is made of molybdenum as an important but very minor ingredient, frequently used in amounts as low as one-quarter of one per cent, both for itself and to intensify the effect of other alloys present. Molybdenum is claimed to have a powerful beneficial effect in providing a fine-grained micro-structure after heat treatment, with increased ductility and tensile strength. Reputedly unique among alloy metals, molybdenum does not interfere with welding; likewise it facilitates certain scale removal. In 1929, addition of small quantities of molybdenum to cast iron was introduced. Since then, its use for this purpose has almost doubled every year. It is reported to impart to castings increased strength, toughness, and resistance to creep and abrasion, reduced porosity, and improved machining and high-temperature properties.

Structural purposes requiring high strength or resistance to abrasion constitute perhaps the most important outlet for molybdenum steels. These are used, for example, for airplane tubing, artillery, and for crushing and grinding machinery. One of the large automobile manufacturers is at present extending the use of carbon-molybdenum steels to springs and other automotive parts. Corrosion-resistant and "stainless" steels are improved by addition of somewhat greater proportions of molybdenum. Two to four per cent is added to high chrome-nickel steel used for chemical equipment. The chemical and pertroleum industries likewise use molybdenum steels because of their greater strength at high temperatures, a property which boiler tube manufacturers utilize to provide thinner and hence more efficient walls.

The most recent triumph of molybdenum is replacing tungsten in high-speed cutting-tool steels, now the chief market for tungsten. Molybdenum alloys have been used for some time for related purposes such as hack-saw blades, oil-well drilling tools, and hot work dies, and chrome-silicon-molybdenum steels are being tried with some success for chisels, wrenches, etc. Attempts to replace tungsten with molybdenum in the standard 18 (tungsten)-4 (chromium)-1 (vanadium) cutting steels had for many years been unsuccessful. Recent investigations, however, indicated the usefulness of compositions substituting one part molybdenum for each two parts tungsten eliminated and leaving just one part tungsten for every four parts molybdenum added. The new 8-2-4-1 composition which followed was injured, however, by existing heat-hardening methods and not until the development during the past few months of improved methods of atmospheric control did it become successful. It is now reported to duplicate, with increased toughness, the cutting ability of the tungsten steels at the economy permitted by substitution for tungsten of half the weight of molybdenum, which is comparably priced in world markets, considerably cheaper behind our tariff wall, and much more reliable as a source of supply.—Bulletin of Arthur D. Little, Inc., Chemists-Engineers, February, 1935.

---

## PITTING OF THE 18-8 IN NAVY USE.

Rumors of serious failures of corrosion-resisting steel in warships of the U. S. Navy have been circulating for several months, and finally reached publication on the first page of the "New York Times" and an Associated Press dispatch saying the Navy had decided to eliminate such steel from vessels now under construction. This bad news (quite inaccurate) has traveled fast, and, although quickly denied by responsible naval officers, has disturbed many consumers of the corrosion-resisting steels, and raised some doubts as to the utility of these alloys for severe service. The facts are worthy of record:

The Bureau of Construction and Repair, U. S. Navy, has been interested in corrosion resisting steels ever since their commercial production. They offered opportunities for weight saving and permanence when replacing galvanized steel or wrought iron; the latter either had to be used in extra heavy section to provide for corrosion losses or replaced before the ship became obsolete. Weight saved on the top sides increases the stability of the ship and permits an equal increase in power plant or armament. Consequently the Navy has put an important tonnage of strip and sheet analyzing 18 per cent chromium, 8 per cent nickel (the so-called 18-8) into deck houses, floors, hatch covers, and a variety of other structures exposed to atmospheric corrosion in port and to dashing spray or water in a seaway. In these places the metal has served excellently, and the Navy has no intention of avoiding such uses in the future. The same may also be said of some other applications of corrosion-resistant steel where the metal is attached to the hull so it is submerged almost continuously, such as rods and arms for operating diving fins on submarines, and stranded wire cables for mooring.

These satisfactory results encouraged the naval constructors to put corrosion-resisting steel into two applications in which unfortunately it did not stand up—namely, gasoline stowage tanks and fire lines. Let us examine the circumstances surrounding such failures.

Salt water is pumped into the bottom of the tanks so the gasoline can be drawn off under hydraulic pressure at all times; consequently the stowage tanks contain variable quantities of gasoline, doped with tetra-ethyl lead and ethylene dibromide, and sea water more or less fouled with marine organisms or diluted sewage. Tanks on the first aircraft carriers had been made of galvanized steel plate, welded, with welds tinned—a reasonably satisfactory construction. On the newer ships the tanks were to be built into the hull in quite inaccessible locations, and the use of 18-8 promised absolute immunity from leakage (most dangerous in confined spaces aboard ship!) for the entire life of the hull.

The second unsatisfactory experience was with fire lines of thin-walled seamless tubing, installed on the latest 10,000-ton cruisers. In older ships galvanized steel or iron pipe has been used, much heavier in wall thickness and of less life than the hull. It was anticipated that the 18-8 would resist sea water perfectly, and not only save considerable weight, but also the cost of expensive replacements.

In both situations the stainless steel failed by pitting in as short a time as six months! These two are the applications which have given all the trouble, which are being removed from existing ships, and which will not be resumed until the cause is definitely known and cured. It would be a disservice to corrosion-resisting steel to gloss over the facts, and allow other users to stumble into similar troubles. A multitude of laboratory salt spray tests and extensive naval experience prove that commercial 18-8 is totally resistant to common salt (sodium chloride), sea salt and sea water when moving vigorously and aerated, or to seashore and marine atmospheres. Trouble by pitting arises from more or less stagnant sea or harbor water, and there is not the least cause for worry about a multitude of applications in dozens of industries where chloride ions, stagnant solutions, and foul deposits are not encountered or not permitted.

Very serious study has been given to these failures, both by naval personnel and various metallurgists. It would be well to list some of the findings to date.

The first gasoline tanks were of welded plate, and the heat treatment subsequent to fabrication was improperly done. Damaging pits occurred in locations where the metal had not been quenched rapidly enough in final heat treatment, a condition which makes 18-8 susceptible to intergranular corrosion, as is well known. To avoid this condition on later tanks they were

made of metal higher in alloying elements (approaching 19 per cent chromium, 9 per cent nickel), lower in carbon content, and unusually clear of solid nonmetallic inclusions—all matters which are believed to increase the stability of the alloy—yet serious pitting occurred in a few months! Location of these pits could not be correlated with welds, bends, or position of plate. Large areas were unaffected. Some pits were so small or tightly closed as to elude careful inspection and were located only by "weeping" of gasoline outside. The under-surface cavities, when cut into, are of various shapes, and contain entrapped moisture so tenaciously that bubbles of corrosion products are exuded even after months in dry, warm storage. Others are open at the top, as big as oyster shells.

Pits in the fire-line piping were also independent of position, proximity to welds, pipe ends, or contact with dissimilar metals. Cast 18-8 valve fittings were penetrated as rapidly as the pipe walls only 25 per cent as thick, leaking through spongy areas in bodies and flanges.

The conclusion which may be reached from the data is that general attack by chemical reaction with sea water is not a factor in these two services; neither is corrosion by oxidation, by intergranular attack, nor by electrolysis set up by contact with dissimilar metals. Some experimenters blame the trouble on (*a*) "contact corrosion" under nonmetallic substances (either scale or inclusions), or under solid particles brought in by the water, or (*b*) corrosion by "oxygen concentration cells" existing in porosities and pits or caused by lodgment of organisms or even dead organic matter which has a reducing or deoxidizing nature.

If these conclusions are correct, then a successful 18-8 for these two services must be free of nonmetallic inclusions with polished surfaces, and the sea water must be filtered even of microscopic organisms and particles of metal from pumps or valves. Obviously, none of these requirements can now be met, either by steel maker, fabricator or naval engineer, and the decision to abandon 18-8 for gasoline tanks and fire lines until more accurate information is available is not to be criticized. On the other hand, investigation may show that the situation is not nearly as hopeless as it appears to the theorist.

It is noteworthy that the conditions for successful naval service differ from the unsuccessful ones in that the sea water in the first case is freely circulating and well aerated, whereas in the latter it is relatively stagnant. Idle boats in lake waters also pit severely, whereas busy boats have no such troubles with hull plates!

Extensive experimentation by research laboratories of at least two steel producers indicates that attached particles of matter, either organic or inorganic, do not start a pit, even when using harbor water as the corrodent, and particles of muck taken from the damaged pipe and tanks as accelerators. On the other hand, fairly rapid pitting can be induced in 18-8 by special solutions ("pitting solutions," they may be called) such as ferric chloride and sodium hypochlorite, and by certain solids, such as graphite and rubber.

While there is no warrant to draw a close parallel between corrosion in stagnant sea water and in "pitting solutions," some results of experiments in the latter may be informative: The evidence points to irregularities of some sort at the surface as the locus of the pit, where the normal protective coat of oxide is broken and prevented from reforming and attaching itself. Since steels with a low inclusion count pit no less freely than quite dirty ones, it is doubtful that *visible* inclusions are the culprits. Another surface irregularity may be a minor variation in the chemical composition of the iron-chromium-nickel solid solution, and this may be the locus of the trouble.

Some other interesting observations are that a sheet, known to be susceptible to pitting, is almost immune if highly buffed and polished. On the other hand, shearing or sawing out the sample seems to increase the number of pits

growing in from the edge, so cold work of this sort has some accelerating action!

Assuming that variation in chemical composition or presence of oxide may locate the surface defect and be the first cause of a pit, some surface treatment can likely be devised which will remove these irregularities before it gets into service. But whether pitting once started can be stopped will be questioned by a believer in corrosion by oxygen concentration cells. This type of corrosion may start immediately wherever there are porosities of small cross-sectional area in proportion to their depth. Under such circumstances, the electrolyte in the bottom of the hole becomes poorer in oxygen than at the entrance, the oxygen-poor area is anodic to the other, and an electrolytic cell is formed. The products of corrosion (iron, chromium, and nickel ions) are carried to the cathode, that is, to the entrance of the pit, where they oxidize; even if they deposit there, they are unable to protect metal at the bottom of the pit from further attack, with the result that corrosion continues until the metal is perforated.

These considerations lead to the thought that the pitting corrosion may best be avoided by an alloy of considerably different analysis from 18-8—one that it better capable of resisting attack by an oxygen concentration cell. The Bureau of Construction and Repair, U. S. Navy, has therefore considered the desirability of selecting individual ships in each of which will be installed a complete system of pipe of material which offers definite promise of being free from the pitting type of corrosion in sea water. Preliminary investigations indicate five such materials: (*a*) 18-8 with 3 per cent molybdenum; (*b*) 18-8 with 5 per cent manganese and 1 per cent copper; (*c*) monel metal; (*d*) 70 per cent copper, 30 per cent nickel alloy; (*e*) rubber-lined steel. Results of such trial installations will be awaited with the greatest interest.

* * *

While the unexpected failures of 18-8 in two classes of naval service are extremely regrettable, there is no need for consternation among other users. It is not the first misapplication made with a new material—even the corrosion-resisting steels have successfully recovered the ground lost after a failure in a service for which they have been mistakenly recommended when another analysis or another alloy of different nature was far better fitted.

One needs only to recollect the failure of 18 per cent chromium-iron tubes in petroleum refinery service, embrittled by stay at high temperature. Adding 8 per cent nickel to the analysis corrected the trouble. Then there were serious troubles with welded 18-8, corroded alongside the joint, until the proper composition, stabilizing additions, and heat treatment were discovered. Chromium-iron rivets driven in nitric acid equipment would break spontaneously until it was found that temperatures in manufacture and in driving must be strictly limited to 1400 F. Unsatisfactory experiences with 18-8 in both the woolen textile industry and the paper and pulp industry have been cured by adding 3 per cent molybdenum to the alloy. Mirror-finished press plates of 18-8, widely used in making laminated paper products, were found to roughen quickly because of the high coefficient of thermal expansion, and the trouble was cured by a lower cost high chromium alloy having a much lower rate of expansion. Pitting of 18-8 in contact with calcium chloride refrigerants has been prevented by the use of low carbon metal and neutralizing the solution by simply immersing a bag of lime in the circulating system. Even in so simple an application as architectural trim, 18-8 will rust and pit if building filth attaches itself—but in the most severe case the original color can be readily restored by washing with Bon Ami, and rusting and pitting do not re-occur on the finished structure.

In every one of these misapplications—and more might be cited—stainless steel has probably received a black eye and temporarily lost ground. Most

of them have come and gone without handicap of false reports in newspapers. However, technologists, like reporters, learn more from failures than from successes, and in all these instances it has been possible to produce a steel which overcame the difficulties of the previous type, or to make some minor change in the condition of application which cured the trouble.

While the cause and cure of pitting in stagnant sea water has not yet been discovered, the search is vigorous enough to warrant success. We know enough about it already that any intelligent user of stainless steel can appraise the conditions which exist in his service, and determine whether there is any cause for worry. If chloride solutions are handled in high chromium steels they should be kept neutral, entirely free from ferric chloride, in continuous circulation, and free from organic or inorganic solids. Periodic cleaning of the equipment is also quite desirable. Precautions such as these have been in use for years in innumerable water piping systems where an intelligent effort to mitigate corrosion has been made.—"Metal Progress," February, 1935.

## FATIGUE IN MARINE ENGINES.

Throughout the history of marine engineering the signal "Disabled, broken crankshaft" has been followed by delay and expense, or by calamitous disaster, and owners and underwriters have continued to insist on generous proportions in the design of engines. In recent years, however, the need for more than mere caution expressed in low nominal stresses or high factor of safety has become increasingly apparent; and in a paper presented to the North-East Coast Institution of Engineers and Shipbuilders, the field for further scientific investigation of fatigue fracture is presented, with special reference to the marine oil engine, by Messrs R. A. MacGregor and W. S. Burn and Professor Frederic Bacon. The three co-authors consider the problem from the different points of view of the manufacturer of forgings, the engine designer, and the scientist.

One reason why generous crankshaft dimensions giving low nominal stresses are not necessarily effective as a safeguard against fracture by fatigue is now generally recognized. Whereas the nominal stresses are produced by calculable forces applied by gas-pressure or by the bearings in overcoming inertia, and are reduced when a larger diameter of crankshaft is used, the actual working stresses arise in part also from less definite forces called into play by flexure of the bedplate or by wear or misalignment of the bearings. The additional stresses due to such causes can be estimated only roughly, but are certainly greater when larger and stiffer crankshafts are used. In times past, it is believed, crankshafts were commonly safeguarded against such additional stresses by the incidence of difficulties in lubrication: over-heating in the bearings set an upper limit to the loads that could be carried, and, consequently, to the bending moments and stresses in the crankshaft. The introduction of forced lubrication with other changes appears to have made the danger of fatigue more imminent in respect that it is no longer necessarily preceded by over-heating in the bearings. The racing of the propeller in bad weather is still probably a cause of fatigue cracking; and, on this account, the endurance of metals under high ranges of stress deserves consideration, as well as the fatigue limit.

As any collected list of failures is apt to induce feelings of despair akin to the transient emotions inspired by a visit to a pathological museum, the writers of such papers would do well to indicate, at least briefly, the circumstances in which the breakdowns were actually experienced. In the case of marine oil engines, it would be desirable if possible to state the mean-effective pressure and the piston speed of the engine. The power of any given engine

is directly proportional to the product of these two factors, and difficulties of different kinds are experienced when increase of power is sought by raising either factor alone. The round numbers of 100 pounds per square inch and 1000 feet per minute are serviceable as convenient bases of comparison for such purposes. The use of the mean-effective, instead of the maximum pressure as a basis of comparison for fatigue conditions may seem anomalous; but it may be borne in mind that temperature stresses increase with mean-effective pressure, and that these stresses—although they do not vary rapidly—nevertheless tend to provoke fatigue fracture because they govern the range of stress that the metal can resist without cracking.

Cooling arrangements in oil engines require careful consideration, not only in relation to combustion and to thermal stresses, but also on account of the peculiar danger of corrosion fatigue which may provoke fracture with very low ranges of stress. Although mild-steel appears to stand as well as high-tensile under corrosion fatigue conditions, both are liable to this dangerous conjoint chemical and mechanical action, and it thus appears that oil is safer than water as a cooling medium.

Although hardened and tempered alloyed steels are necessarily used in aircraft, being specially effective in the smaller shafts suitable for such light types, it appears that the use of mild steel is extending in larger engines for marine duty. For bedplates in particular, the use of mild steel offers the great advantage that well-designed welding will stand the full range of stress that can be permitted in the riveted (or welded) under-structure, which an iron-casting cannot: thus the safety of a welded steel bedplate is not dependent on the rigidity of the vessel, and a lighter bedplate of more efficient design can be used, with suitable precautions against flexure of the crankshaft.

Our editorial columns in the past have borne witness to the remarkable reliability of mild steel in practical experience and in fatigue tests, when "stress-raisers" militate against safety. This is endorsed by Mr. MacGregor, who draws a comparison between a hardened and tempered nickel steel and a normalized mild steel. Although the harder steel is nearly twice as strong as the mild when tested in the ordinary Wöhler manner with smoothly finished testpieces, the fatigue limits are nearly alike when the testpieces are formed with sharp shoulders: whereas the harder steel loses nearly two-thirds of its strength, the mild steel loses only about one-third through the action of the sharp shoulder. Such differences are attributed by Professor Bacon to hysteresis, and it is believed that many other investigators now hold the same opinion: "The view held some years ago, that the onset of plastic distortion was the feature that controlled the fatigue strength of a material, has got to be abandoned." In some metals that appear nearly ideal in their elasticity, the fatigue limit is relatively low and liable to be much further reduced by stress-raisers; while in other metals the fatigue limit may be more than four times the highest stress at which the distortion can be said to be purely elastic. It appears that much of the value of a fatigue test is thrown away when only the fatigue limit is determined and that more attention might well be directed to the study of hysteresis.

Mr. MacGregor refers to certain tests, carried out at Greenwich and recently described in our columns, tending to show that the reliable qualities of mild steels may be found also in certain lightly alloyed steels of high tensile and fatigue strength. It appears that 40 per cent to 50 per cent greater strength may be attainable with little if any increase in sensitivity to stress-raisers of standard type.

Undue confidence in size, or in lower nominal stresses, have often in the past tended to obscure the importance of stress-raisers in engine-design; experience indicates that the safety of an engine against fatigue failure may be secured more effectively by careful attention to detail than by mere in-

crease in size. Mr. Burn cites a number of failures arising from important details, and it is sad to reflect that in some instances increase of size has actually reduced fatigue strength, as it has involved reduction of fillet radius.

The use of larger numbers of threads per inch on bolts that have to resist fatigue is recommended not only on account of the larger core diameter, but also for better distribution of stress; and it is interesting to recollect that, many years ago, Admiralty designs were criticized on account of the use of non-standard fine threads in such cases. The policy is now more generally appreciated, but merits further investigation. The prospect of any change in standard threads may strike dismay, but it seems probable that the more general use of an existing standard fine thread may suffice to meet the requirements. As a trifling increase in the diameter of a connecting rod bolt is said to add pounds to the weight of the big end and tons to the weight of the engine, and as other results of the change may be even more unfortunate, it is probable that the scientific investigation of such details would well repay attention.—"Engineering," February 1, 1935.

---

## MARINE ENGINES FROM A SUPERINTENDENT ENGINEER'S POINT OF VIEW.

By Sterry B. Freeman, C.B.E., M.Eng.*

From the economic standpoint, the provision of machinery in a ship is a regrettable necessity. It occupies valuable space, usually in the most commodious part of the ship; machinery casings interfere with the deck spaces, and, generally speaking, the less room the engine and its fuel occupy the better for the economic return. The superintendent has to restrict the space which the machinery occupies, both in length and height, and also cut down the weight as far as may be prudent, always remembering that transport of cargo is provided for the convenience of shippers, not for the edification of engineers. Every refinement introduced into the engines has to be paid for, both on its installation and for its maintenance; the provision of stand-by and emergency plant has also to be carefully considered, and it may be necessary to do without many tempting details, which cost as much as though they were part of the essential running outfit and need upkeep expenditure too. As a rule, the plainer the machinery the greater the accessibility for overhaul and repair, which helps to reduce the cost of upkeep. It is a notable point that, assuming the right type of machinery has been selected to suit the conditions, sound design has a great effect upon the cost of running, for it is not mistakes in fundamental principles that lead to expensive renewals and repairs, but errors in detail.

Since we must have machinery, however much we may restrict its infringement on the cargo space, it must be ready at any time to face the worst that nature can do in the matter of weather. The soul of the sailing ship was in her sails, but the soul of the modern floating hotel or warehouse is in the engine room, and from the superintendent's point of view the interests and duties of the surveyor and his own are identical, in that the first requirement of any marine equipment is safety. The cardinal virtue in a marine engine is reliability. The three factors ensuring this quality are sound design, material and workmanship; and the superintendent envisaging the building of new marine engines, or keeping old engines running in service, has to learn and apply all he can of good practice in these three essentials to ensure freedom from trouble.

* Abstract of a paper read before Lloyd's Register Staff Association in London on January 10.

### SINGLE-SCREW OR TWIN-SCREW.

One of the easy ways in which the superintendent can obtain reliability is to adopt a twin-screw design. It is rarely the case that both engines will fail at the same time. Considerations of space and weight and of additional staff come in and may rule the twin screw out of court. The installation of a high-pressure and a low-pressure turbine, or two oil engines, each driving a pinion shaft on a common gear wheel and one line of shafting is a half-way house between the twin- and the single-screw ship. Some long passages have been made on either high-pressure or low-pressure turbine after the other section of the turbine or its pinion has failed. Both the reciprocating steam engine and the heavy-oil engine can, of course, run with less than their full complement of cylinders, and one of our oil engines has come home from Australia running perfectly well and steadily, and at full power, with one of its eight cylinders cut out the whole way.

In the design of the modern ship, speed has its place. The speed required of the ship has an effect on the design of suitable engines, and it is remarkable how rapidly the horsepower required increases with the speed. The present trend of high speeds is expensive and is not suitable for the carriage of cargo on which only small freights are earned. It is for this reason that many of the high-speed cargo vessels make many voyages at comparatively low speeds, and only use their full power when required.

This demand for additional speed and increased economy of operation has led to the employment of types of machinery, systems, and methods which previously would have been felt unduly risky. At the same time, the trend is towards simplicity, so far as the accepted types of turbine and oil engine are concerned. The addition to the reciprocating engine of efficient valves and an exhaust turbine cannot better the performance of the turbine, and may increase the cost of upkeep. For the highest powers the right choice is still the turbine, working, of course, with superheated steam at high pressure. The statistical returns of the society show the advance the oil engine is making, especially for moderate-power installations, and that oil fuel burnt in the engine or in the furnace is a necessity for the large passenger ship.

### ECONOMICAL SPEED.

From physical considerations it may be possible to prove that 9 or 10 knots is the most economical speed to move general cargoes about the world. The higher the speed of the ship the smaller the carrying capacity, due to the finer lines of the hull, increased bunker spaces, and greater weight of machinery. But the shipper wants payment for his goods as early as possible; values may fluctuate while the cargo is afloat. The sooner freight is earned the sooner the vessel is released to earn fresh freight, possibly at higher rates; running costs go on, wages, victualling and insurance mount up, and, beyond all these, there is a satisfaction in "getting on," which we all recognize. A vessel known to be slow is shunned and a faster ship favored. Passengers are even more swayed by speed. It was predicted, when wireless telegraphy came into use at sea, that faster ships would not be found necessary, since one could keep in close touch with affairs, the markets, etc., and carry on one's business as though in an office ashore. This has not yet been the case, as is obvious by the building of recent high-speed liners. A more significant omen is now observed in the scheduling of passages to far parts of the world by air, which service, if developed successfully, may lessen the demand for the fast passenger ship. The engineer is required, by the pressure of circumstances, to design for more and more power from less

and less space and weight, so that the higher speed may be obtained from engines which are no larger and no heavier, and consume relatively no more fuel.

There is, of course, a great difference between the most efficient and economical propelling plant to suit the requirements of a fast passenger liner, a cargo liner, a tramp and a coaster. The conditions of an Atlantic passenger liner, where high powers and absence of noise and vibration are first essentials, where there is no great restriction on weight of machinery, where—although head-room is restricted—there is ample room fore and aft at the bottom of the ship for bunkers and machinery, and where oil is dear but essential and coal cheap but impracticable, are very different from those obtaining in a cargo liner trading to the Far East. Here speed is comparatively low, vibration and noise are not a bugbear, ships load to their full capacity both as regards space and deadweight, oil is cheap and coal frequently dear. In addition to the differences of atmospheric engine-room and sea temperatures, there are draught limitations, loading conditions and weather differences between an Eastern and a Western voyage to be considered. The tramp and the coaster, as a rule, are compelled to adopt the simplest type of machinery, as the questions of first cost and of personnel come in, but, as you know, there is a trend in these fields also towards the more complicated but more efficient plant. As racing men say, "Horses for courses," and the superintendent falls back on the only safe plan of putting down the details on paper and working out the returns on the different proposals possible.

A few years ago the oil engine would not have been considered as reliable as the steam engine. Today, apart from experimental designs, there is little to choose between the two, although the conservative instincts of some of us cause us to cling to the idea that the old massive, slow-running, open-fronted, main engine supplied with saturated steam from Scotch boilers is the acme of reliability. The need for economy in fuel and in space and weight has brought the light, fast-running, forced-lubricated type of engine supplied with superheated steam from water-tube boilers to the forefront. The work of the turbine designer, the gear cutter, and the metallurgist have made this new conception of the marine steam engine an equally reliable alternative. As has been pointed out elsewhere, the high thermal and overall efficiency of the oil engine has spurred on developments in the steam engine and steam boiler, giving the shipowner a wide choice as to his prime mover.

The steam engine is greatly helped in competition with the oil engine by the recent developments in the water-tube boiler, which we are all watching with interest. The present position is that the turbines plus Johnson boilers, as in the *Asturias,* occupy no more space than the old four-stroke-cycle, double-acting oil engines which they replace, develop more power, and are of less weight. In either case the only fuel at present practicable is oil. The consumption of oil per S.H.P. hour is, in the case of the turbine installation, approximately 0.6 pound, and in the case of the oil engine approximately 0.4 pound. These figures may be shaded off to, say, 0.57 and 0.365 pound in certain cases, but the general consideration remains that 50 per cent more fuel must be carried in the case of the turbine than in the oil engined ship. The oil for the oil engine will be more expensive than that for the water-tube boilers, and that cost must be set against the provision of the necessary bunker space and the possible shutting out of cargo. We are now promised still further developments of the steam producer: the Benson boiler, after prolonged trials in the *Uckermark,* is being fitted in more merchantile ships; the Velox boiler, promising rates of evaporation about five times as great as in present practice; the Loeffler boiler, evaporating water by superheated steam; and the Sulzer single-tube boiler. It would be pleasant and popular if

one could record that these new steam producers opened up a field for the use of our coal again, but they do not. It may be they can utilize powdered coal in some form, but then the question of transport of the necessary quantity of bunkers comes in once more, and the other handicaps under which coal labors—space, handling, dust and dirt, ashes, corrosion of bunkers and steel work, delay in bunkering, loss of steam while cleaning fires, and so on.

When considering the oil engine, the possibility of further economies is not so apparent. It has been obvious for some years now that the goal toward which oil-engine designers must work from the original four-stroke-cycle single-acting engine with blast-air injection of fuel was the two-stroke-cycle double-acting engine with airless injection of fuel and the exhaust-gas boiler. This has now arrived, but there has been little alteration in the rate of fuel consumption. There is a tendency to increase the maximum pressures, which results in a reduction of fuel consumption. The earlier engines operated at about 500 pounds per square inch maximum pressure, the later airless-injection engines at about 850 pounds per square inch.

The general conditions under which the propelling machinery of various types will operate are set out below:—

| | Coal | Oil |
|---|---|---|
| Fuel values:— | | |
| Available heat in fuel, Btu. per pound | 15,000 | 19,000 |
| Probable average value | 12,500 | 18,000 |
| Boiler efficiency:— | | |
| Cylindrical boilers, per cent | 65–75 | 77–82 |
| Water-tube boilers | 75–80 | 85–88 |
| Mechanical efficiency of engines:— | | |
| Reciprocating steam, per cent | 90 approximately | |
| Oil engines, depending upon type, per cent | 72–88 | |
| Overall thermal efficiency:— | | |
| Reciprocating engines using saturated steam, per cent | 11 | |
| Reciprocating engines using superheated steam, per cent | 13.5 | |
| Reciprocating engines and exhaust turbines using superheated steam, per cent | 16 | |
| Turbines and gearing working at low pressures and temperatures, per cent | 16 | |
| Turbines and gearing working at high pressures and temperatures and using oil-engine-driven generators for auxiliary power, per cent | 24-27 | |
| Oil engines with air injection of fuel, per cent | 35 | |
| Oil engines with airless injection of fuel and high maximum pressure, per cent | 40 | |
| Oil engines with waste-heat boiler, per cent | 37 | |
| Oil engines with heat recovery on Still system,* per cent | 43 | |

The relative fuel consumption can be obtained from these values.

It will be evident that in the case of the tramp and the coaster the comparison will lie between the low-pressure boiler and steam reciprocating machinery, probably using saturated steam, and the simpler forms of single-acting oil engines, plus waste-heat boiler. The former plant is of much less economy than the latest steam engines and boilers, whereas the latter plant will be nearly as economical as the latest types of oil engines.

To obtain a straight comparison of the two types of machinery, steam and oil, 8000 S.H.P. has been taken as a basis. That is a power which can conveniently and economically be developed in either a steam or an oil

* See Prof. C. J. Hawkes' Thomas Lowe Gray Lecture, "Proc. I. Mech. E.," 1928, vol. i, page 6.

engine. The oil engine of this power would be of the two-stroke-cycle, double-acting type if built as a single-screw unit.

Several builders of steam-reciprocating and steam-turbine and oil engines have been good enough to give me figures for the ratio of cost between the different types of machinery for the same horsepower under discussion, and these are given in Table I.

| | A | B | C | D | Range of prices |
|---|---|---|---|---|---|
| Steam reciprocating | 1·0 | 1·0 (0·985 if W.T. boilers) | 1·0 (twin screw) | 1·0 | 0·985–1·0 |
| Steam reciprocating with Bauer–Wach turbines | 1·13 | — | — | — | 1·13 |
| Geared turbines .. | 1·27–1·33 | 1·142 | 0·97 (single screw) | 1·3 | 1·142–1·33 (0·97 if single screw) |
| Turbo-electric .. | 1·47 | 1·44 | 1·06 (single screw) | 1·4 | 1·4–1·47 (1·06 if single screw) |
| Oil engines .. | 1·33 | 1·35 | 1·34 (twin screw) | 1·47 | 1·33–1·47 |
| Oil engines, electric transmission | 1·66 | 1·69 | — | 2·1 | 1·66–2·1 |

TABLE I—COMPARISON OF PRICES FOR VARIOUS TYPES OF PROPELLING MACHINERY OF ABOUT 8000 S.H.P.

These prices refer to the particular types of vessels built by the respective shipbuilders. It should not be assumed that they refer to competitive prices quoted for the same vessels by the various builders.

Table II gives a comparison of the running costs of different types of machinery of this same 8000 S.H.P., where the ratio of first cost, rate of fuel consumption, and the details of running cost have been taken from actual experience.

Dealing with the items included in the running cost per annum, it will be understood that the cost of fuel is not made public by shipowners, but it is safe to say that some such ratio as coal 1, boiler oil fuel 1.75, engine oil fuel 2.15, would not be very wide of the mark. The cost of repairs in our experience, does not vary much between ship and ship, age having more to do with the amount of repair than the type of machinery. You surveyors will, I think, bear me out in saying that in modern machinery of those types which have been accepted as standard there is little repair to be done beyond the normal renewal of wearing parts. Stores include all that is used in the running of the engines except the fuel. Generally, it is the cost of the lubricating oil which increases the cost of the stores for the motor vessels. The wage bills for the engine-room complement for the various types of machinery do not vary much, except, of course, for twin and single-screw machinery. In motorships, where firemen are not required, the saving is wiped out by the cost of the necessary electricians and extra cleaners. The cost of victualling is dependent upon the crew carried, and again there is not the difference one might expect. The depreciation of the machinery and hull is a difficult matter to decide. Some owners build a ship to run 25 to 30 years, whereas others prefer to sell them when only 15 years old. Each case must, therefore, be decided on its merits.

| Proposal | Oil Engines | | | High-Pressure Turbines | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | A | B | C |
| Type of machinery | 4-stroke, single-acting, super-twin screw | 2-stroke, double-acting, twin screw | 2-stroke, double-acting, single screw | Coal-fired boilers, twin screw, mechanical stokers | Oil-fired boilers, twin screw | Oil-fired boilers, twin screw, electrical auxiliaries |
| Ratio of machinery costs .. .. | 123 | 117 | 113 | 101 | 100 | 110 |
| Fuel per S.H.P.-hour .. lb. | 0·40 | 0·40 | 0·40 | 1·00 | 0·71 | 0·60 |
| Fuel per day tons | 34·5 | 34·5 | 34·5 | 86 | 61 | 51·5 |
| Running cost per annum, including :— Fuel .. Stores .. Repairs Wages .. Victualling 4 per cent. depreciation | £29,600 | £29,400 | £28,600 | £36,700 | £39,000 | £31,700 |

| Summary of costs | | 1 | 2 | 3 |
|---|---|---|---|---|
| | | £ | £ | £ |
| Saving per annum compared with | A | 7,100 | 7,300 | 8,100 |
| | B | 9,400 | 9,600 | 10,400 |
| | C | 2,100 | 2,300 | 3,100 |

TABLE II—COMPARISON OF RUNNING COSTS OF OIL ENGINES AND HIGH-PRESSURE TURBINE MACHINERY OF 8000 S.H.P.

In Tables I and II, steam reciprocating engines have Scotch boilers working at 220 pounds per square inch unless otherwise stated. Geared turbines and turbo-electric have water-tube boilers working at 400 pounds per square inch. It will be noticed that there is not so great a difference in the cost of steam turbines and oil engines as might be imagined.

The matter of repairs and renewals is extremely important both from a cost and a reliability point of view. It is interesting to compare the cost of repairs for the various types of vessels, but rather difficult to obtain a good idea of these in a fleet of vessels which is kept up to date. In such fleets the steam reciprocating engines, steam turbines and motor vessels were generally added at different times, *e.g.*, steam reciprocating engines prior to 1922, turbines from 1920 to 1925, and since then oil engines. There are sure to be exceptions to this as many firms have distinct preferences for particular types of machinery, but the above dates give an idea of what happened in many cases. It is thus difficult to give correct ideas of the relative costs of upkeep as there may be 10 or more years' difference in the ages of the types of engines under comparison, which makes a big difference in repair bills. Also, the oil engines built in 1924 are liable to be more expensive in upkeep than modern machinery, but this is not always so as the earlier engines were more lightly rated and consequently breakdowns due to heat stresses fewer.

To deal effectively and economically with repairs it is of great value to have reliable and adequate records of wear. In addition to the wear-down

| | Age | S.H.P. | Repairs | Stores |
|---|---|---|---|---|
| | Years | | Per cent. | Per cent. |
| Single-screw reciprocating saturated .. .. | 23 | 4,000 | 100 | 100 |
| Twin-screw ,, ,, .. .. | 29 | 5,500 | 105 | 110 |
| Single-screw superheated .. .. .. | 20 | 4,300 | 105 | 111 |
| Twin-screw ,, .. .. .. | 28 | 4,500 | 125 | 116 |
| ,, ,, (passenger ship) .. | 24 | 5,000 | 190 | 165 |
| ,, ,, ,, ,, .. | 21 | 6,000 | 230 | 175 |
| Single-screw coal-fired turbine .. .. | 13 | 6,000 | 99 | 112 |
| Twin-screw ,, ,, (passenger ship) | 10 | 7,500 | 180 | 205 |
| ,, ,, ,, .. .. .. | 13 | 6,800 | 195 | 149 |
| Single-screw oil-fired turbine .. .. .. | 13 | 6,000 | 75 | 110 |
| ,, ,, ,, .. .. .. | 10 | 3,700 | 70 | 95 |
| Twin-screw ,, ,, (passenger ship) | 10 | 7,500 | 120 | 170 |
| Twin-screw oil engine .. .. .. .. | 9 | 3,700 | 62 | 160 |
| ,, ,, .. .. .. .. | 8 | 6,000 | 88 | 200 |
| ,, ,, (exhaust-gas super-charge) | 4 | 5,500 | 55 | 160 |
| ,, ,, (chain-driven super-charge) | 4 | 8,600 | 110 | 175 |

TABLE III—COMPARISON OF COST OF REPAIRS AND STORES FOR ENGINES OF VARIOUS TYPES.

gages supplied for the turbine main bearings and the reciprocating-engine crankshaft, records should be kept of the wear down of the tunnel shafting. The gaging of the distance between the inner faces of the crank webs as the shaft is revolved in its bearings is another useful method of detecting abnormal wear. This method of testing for alignment has been found especially useful in the case of crankshafts driving heavy generators with a common main bearing for crankshaft and generator on the inner side; a typical set of readings is shown in Figure 1. Boiler defects and cracks and oil-engine cylinder-head cracks should be noted and any extensions kept under observa-

VESSEL: "AENEAS" PORT: LIVERPOOL DATE: AUG., 1934

RECORD OF GAGINGS BETWEEN WEBS OF MAIN ENGINE CRANKSHAFT.

| Position of Crank | Port Engine | | | Starboard Engine | | |
|---|---|---|---|---|---|---|
| | H.P. | M.P. | L.P. | H.P. | M.P. | L.P. |
| Top centre .. | 0·261 | 0·262 | 0·275 | 0·272 | 0·245 | 0·229 |
| *Difference top and bottom centre* .. | *0·005* | *0·004* | *0·004* | *0·001* | *0·002* | *0·009* |
| Bottom centre .. | 0·266 | 0·258 | 0·279 | 0·271 | 0·247 | 0·238 |
| Starboard centre | 0·264 | 0·264 | 0·280 | 0·273 | 0·247 | 0·237 |
| Port centre .. | 0·263 | 0·258 | 0·272 | 0·272 | 0·244 | 0·232 |

GAGINGS ARE IN EXCESS OF 14-INCH WIDTH BETWEEN WEBS AND ARE EXPRESSED IN THOUSANDTHS OF AN INCH.

FIGURE 1.—TYPICAL SET OF READINGS FOR CRANKSHAT ALIGNMENT TEST.

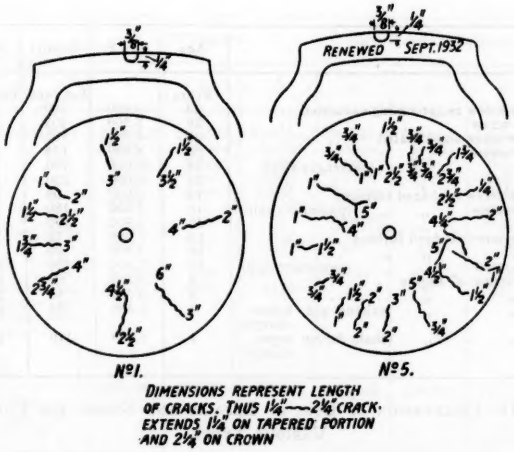

RENEWED SEPT. 1932
No 1.
No 5.
DIMENSIONS REPRESENT LENGTH OF CRACKS. THUS 1¼"—2¼" CRACK EXTENDS 1¼" ON TAPERED PORTION AND 2¼" ON CROWN

FIG. 2.—RECORD OF CRACKS ON TOP OF OIL CYLINDERS. M.V. "EURYBATES."

tion. It is found that while records of oil-engine cylinder-liner wear are always taken and studied in the case of main propelling units, they are not always so closely kept up in the case of main-engine steam cylinders and of auxiliary machinery as they should be. Typical records are shown in Figures 2 and 3.

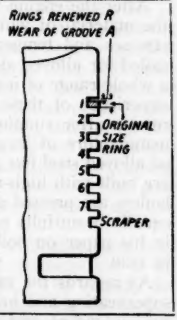
In the case of turbine ships, such details as blade clearances, bridge-gage readings of rotors, pinions, and gearwheel shafts are of real importance. Records of propeller and propeller-shaft damage are most necessary, and it is surprising to find the amount of small damage to propellers that takes place. Such records show that in a fleet of 80 ships 207 accidents occurred to propellers in 20 years. Of these, 111 were in respect of single-screw ships and 89, or 43 per cent of the total, twin-screw ships. For years very detailed records were kept of the condenser-tube failures, showing the type of failure, position in condenser and in tube, and so on. It is a matter of thankfulness that the introduction of reliable tubes has made it unnecessary to maintain these records.

Each ship has a large data book in which is kept the particulars of the main and auxiliary machinery, the spare gear, the records of dry docking, surveys held, examinations of machinery, principal renewals and repairs, and the above records of measurements, so that the past history of the plant can be immediately traced on the ship. The vessel's final summary of log for each voyage is also entered in this book, so that the chief engineer may know what has been done on previous voyages. This book is kept in duplicate, one copy on board and one in the superintendent's office, and the copies are exchanged at the end of each voyage so that the superintendent also has a copy of the ship's history before him.

Careful records are also kept of the cost of repairs and stores to the various ships, and Table III gives the ratio of costs for supplying stores and carrying out the necessary repairs to the engines and auxiliaries for various machinery types.

RECORD OF WEAR ON PISTON RING GROOVES. READINGS IN THOUSANDTHS OF AN INCH.

| Cylr. No. | 1. | | 2. | | 3. | | 4. | | 5. | | 6. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 5-9-32 | | 5-9-32 | | 5-9-32 | | 5-9-32 | | 5-9-32 | | 5-9-32 | |
| Port | Birkenhead | | Birkenhead | | Birkenhead | | Birkenhead | | Birkenhead | | Birkenhead | |
| Ring No. | A | R | A | R | A | R | A | R | A | R | A | R |
| 1 | 0·007 | — | 0·007 | — | 0·005 | — | 0·005 | — | 0·005 | — | 000·6 | — |
| 2 | 0·004 | — | 0·004 | — | 0·003 | — | 0·003 | — | 0·003 | — | 000·2 | — |
| 3 | 0·005 | — | 0·003 | — | 0·002 | — | 0·003 | — | 0·003 | — | 0·002 | — |
| 4 | 0·005 | — | 0·003 | — | 0·003 | — | 0·002 | — | 0·002 | — | 0·003 | — |
| 5 | 0·003 | — | 0·003 | — | 0·003 | — | 0·002 | — | 0·002 | — | 000·3 | — |
| 6 | 0·003 | — | 0·003 | — | 0·002 | — | 0·004 | — | 0·004 | — | 000·3 | — |
| 7 | 0·002 | — | 0·003 | — | 0·002 | — | 0·002 | — | 0·002 | — | 000·2 | — |
| Scraper | 0·002 | — | 0·002 | — | 0·003 | — | 0·003 | — | 0·003 | — | 000·3 | — |




CYLINDER GAUGINGS IN EXCESS OF 620 M/M. READINGS REQUIRED IN THOUSANDTHS OF AN INCH

| | Position | A | B | C | D | E | F | G | H | — |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F. & A. | 0·018 | 0·012 | 0·008 | 0·007 | 0·006 | 0·010 | 0·008 | 0·004 | Date, 5-9-32 |
| | Ath. .. | 0·018 | 0·010 | 0·008 | 0·008 | 0·007 | 0·010 | 0·006 | 0·006 | Port, Birkenhead |
| 2 | F. & A. | 0·018 | 0·018 | 0·008 | 0·006 | 0·004 | 0·005 | 0·004 | 0·003 | Date, 5-9-32 |
| | Ath. .. | 0·014 | 0·010 | 0·006 | 0·006 | 0·006 | 0·006 | 0·006 | 0·003 | Port, Birkenhead |
| 3 | F. & A. | 0·018 | 0·016 | 0·012 | 0·008 | 0·004 | 0·008 | 0·006 | 0·006 | Date, 5-9-32 |
| | Ath. .. | 0·016 | 0·008 | 0·008 | 0·008 | 0·006 | 0·012 | 0·008 | 0·006 | Port, Birkenhead |
| 4 | F. & A. | 0·018 | 0·018 | 0·016 | 0·010 | 0·006 | 0·006 | 0·004 | 0·008 | Date, 5-9-32 |
| | Ath. .. | 0·016 | 0·016 | 0·012 | 0·010 | 0·010 | 0·016 | 0·012 | 0·004 | Port, Birkenhead |
| 5 | F. & A. | 0·018 | 0·018 | 0·016 | 0·010 | 0·004 | 0·006 | 0·006 | 0·006 | Date, 5-9-32 |
| | Ath. .. | 0·014 | 0·013 | 0·013 | 0·013 | 0·013 | 0·012 | 0·010 | 0·008 | Port, Birkenhead |
| 6 | F. & A. | 0·021 | 0·020 | 0·016 | 0·010 | 0·006 | 0·006 | 0·006 | 0·006 | Date, 5-9-32 |
| | Ath. .. | 0·016 | 0·016 | 0·013 | 0·006 | 0·006 | 0·013 | 0·010 | 0·006 | Port, Birkenhead |

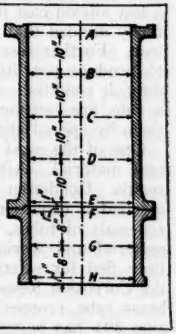



FIG. 3.—EXTRACT FROM RECORD OF GAGINGS, WEAR DOWN AND SURVEYS, M.V. "MARON."

SPEEDS UNDER VARYING CONDITIONS.

The superintendent will often be asked what is the economical speed for a ship. The answer is on these lines. When a ship is on a definite run for long periods, the economical speed will be given by taking into consideration all the running expenses, wages, victualling, fuel, repairs, stores, etc., and depreciation and finding the speed at which the cost of these is at a minimum. If the ship is to go at her most economical speed because of bad trade, then the factor of depreciation in the comparison should be omitted, as the ship presumably could not earn more freight even if the speed were increased and more voyages made. In some companies, the wages of crew are paid whether ship is at sea or not; when this is done the wages will be omitted in working out the most economical speed for bad trade conditions. Before deciding upon the economical speed at which to send a vessel on her voyage, it is necessary to know which of the above three cases is applicable. It should be remembered, however, that the economical speed of a vessel may not be a satisfactory

one from the point of view of obtaining the proper share of cargo, passengers, etc. In fact it may be generally stated that the present-day conditions demand that the cargo liners run at speeds greatly in excess of their economical speed.

After the engine type has been decided the next important consideration is the material of which the component parts will be constructed. The higher stresses and temperatures under which modern machinery is operated has called for alloyed steels, both in forgings and castings, pearlitic cast iron and a whole range of improvements in the non-ferrous metals. You will have had experience of these in the test house and in the works and have seen the results after running under working conditions. The improvements in the manufacture of forged steel have helped the turbine builder, the production of alloyed steel has given confidence in the use of gearing, tank marine boilers are built with high-tensile shells for high pressures, the drums for water-tube boilers are pressed out of the solid ingot in amazing presses and the tubes are equally beautifully produced in such alloys as Dr. Dorey has so well described in his paper on boiler tubes delivered to the Institute of Marine Engineers in 1930.

As regards the cast iron required for the higher temperatures involved in superheating and in oil engine use, the metallurgist came in here to help the superintendent, and we have now no hesitation in subjecting cast iron to temperatures at one time thought to be dangerously high. It was discovered that a low silicon cast iron could be produced in which the carbon content was so finely divided that the splitting action of carbon flakes did not break up the iron. Further research and invention showed the foundrymen how regularly to produce pearlitic cast iron. These cast irons have been tried in those difficult conditions under which the two-stroke cycle oil engines work, and as a rule, are satisfactory, but in cases it has been found necessary to replace them by special chrome cast steel.

One of the most beneficent discoveries has been that relating to condenser tube material. After the war the marine world had an epidemic of condenseritis. Condenser tubes have had a way of failing in cycles, and in 1920-24 we had a visitation. Owners found themselves faced with heavy bills for renewals of tubes. Engine builders were asked to pay claims for defective material and workmanship in these tubes. The Navy and the high-speed liner fled for safety to the expensive cupro-nickel tube. The discovery by the Corrosion Research Committee of the Institute of Metals of the aluminum brass tube (copper 76, zinc 22, aluminum 2, instead of the old copper 70, zinc 30) has solved the problem of an efficient and cheap condenser tube. The use of this tube has had a most marked effect upon the practice of superheating. Superintendents found that those plants which had leaky condenser tubes developed leaky or blocked superheater tubes. The salt water from the circulating side of the condenser passing to the steam side caused priming in the boilers, so that scum and dirt was carried over into the superheater tubes, was baked in them, and soon the tube failed. The erosion and pitting of turbine blades, the wear of reciprocating engine piston rings and metallic packings have all been reduced since condenser tubes have been put right.

In the earlier days some anxiety was caused by turbine blade failure, but the use of manganese copper blades, steel blades, or chromium iron blades has dissipated that care, and we rarely hear of troubles in this connection. Surveyors can help enormously by their supervision of material and workmanship. If these are originally good, the life of the plant is greatly increased and expense lessened. In dealing with the steam engine, it is curious how superheating of the steam in marine practice lagged behind land practice, but it is an essential feature in marine practice today. The maximum temperature at which the materials at present available for superheaters and turbines can be used, at any rate for marine work, is about 750 degrees F.

The efficiency of steam engines cannot be raised to any large extent so far as we can see at present owing to the limitation of temperature by the materials in use. Competition is so keen, however, between the steam and oil engines that it is unsafe to predict that further improvement is impossible or far off. At one time the advocates of the oil engine could point to the gearing of the turbine ship as being a weak spot. I should take space here to say that gearing is now as reliable as any other part of the equipment. Our first gears were designed with a load of 1000 pounds per lineal inch of gear face, and that gearing is running well today. But before that ship had gone to sea, such troubles had been found elsewhere that a halt was called and the loading on the next gear teeth was reduced to 600 pounds. It was not until about 1923 that the cause of the mischief was found to be in defective gear cutting, originating in a cumulative pitch error in the master wheels of the gear cutting machinery. Since gear cutting practice has been tightened up, that source of worry has been largely removed.

In the oil engine the principal troubles for all makes of engine have been the cracking of cylinder heads, liners and pistons and the deterioration of the oil in the crankcase causing undue wear in the bearings. The remedy for these troubles has been the use of fresh water instead of salt for the cooling of the heads and liners, or, where salt is used, the use of acids to remove scale which is deposited on the heating surfaces. The oil can be kept free from water by the simple expedient of using oil instead of water as the cooling medium for the piston.

Having built and run the most desirable engine, it is, of course, of great importance to know exactly what the performance has been, and the engineer in charge sends home his results, measured as accurately as he finds possible. The measurement of results is not easy once the machinery has been installed in a ship. The engineer in a power station ashore has space in which he can marshall his coal and ashes, erect tanks to store his water supplies, and deal with his meters, gages and other instruments. In a ship, space is of value and in the majority of cases the trials carried out at the beginning of a vessel's career are the only ones on which money and time are expended to ensure a correct result. The owner, however, should have some sort of a measuring stick by which to assess the value of his ship's performance relatively to the same ship's previous performances and to those of other ships. For this purpose the Admiralty coefficient and fuel coefficient are very valuable. These formulæ do not take into account the effects of bad weather, bad coal and difficult conditions, but these figures when compared with those of similar ships or previous voyages of the same ship, give a very good idea of the merit of a voyage performance.

Looking back, it is refreshing to note how many of our old troubles have been cured, or at all events lessened, by the advance in technical achievement. The use of electric welding for example, has made unnecessary these very difficult and often unsatisfactory patches which we surveyors used to plan with the superintendent and the foreman boilermaker, the "putting on tool" for which we used to send the youngest apprentice has become a reality, and steel, cast iron and even brass parts are now built up in place, or forgings such as pinion shafts are sent to have nickel or other metal deposited upon the worn parts.

After dealing with these details of marine machinery, it is interesting to consider the conditions under which it is to work. Immediately there will spring to the mind of the older generation a picture of the machinery they used to operate, simple, rather ponderous, hand lubricated, adjusted by rule of thumb methods, and entailing much heavy manual labor in overhaul. The men who dealt with this plant were, as a rule, craftsmen rather than technicians, who were concerned with overcoming the deficiencies of the original design, material and workmanship, as well as with the making good of fair wear and tear.

Today the majority of new ships have machinery which is designed to work at higher speeds, temperatures and stresses and the young men who are coming forward to take charge of this more complicated and exacting machinery are on the whole better equipped technically than their predecessors, although usually less skilful craftsmen. I should like to take this opportunity of bearing testimony to the keenness of the marine engineer. The older men have taken up both turbine and oil engine work with enthusiasm and have faced the Board of Trade examinations for oil engine endorsements with courage and success—no light task when long past school age. The younger men come to us with creditable records of work done in the shops and in the technical schools, often with National Certificates, and work as well and hard as the boys of my early sea-going days.—"Shipbuilding and Shipping Record," January 31, 1935.

## FUEL CONSUMPTION AND MAINTENANCE COSTS OF MARINE ENGINES.*

The items affecting a comparison of the different types of propelling machinery are as follows:—

(1) Cost of machinery (referred to later).
(2) Bunkers.
(3) Engine-room staff wages and provisions.
(4) Engine-room stores, lubricating oil, and water.
(5) Boiler, machinery repairs, and survey.

Basing the costs, for example, on a proposed vessel of 15,500 tons displacement, making loaded passages of 5000 miles, with allowance of 15 per cent surplus bunkers, it is estimated that the vessel will maintain an average speed of 11¾ knots loaded and 13 knots in ballast under all weather conditions. The cargo carried is as folows:—

Machinery.

(*a*) Diesel ..... $462 \times 10^6$ ton/miles per annum
(*b*) Turbine (oil) ..... $446 \times 10^6$ ton/miles per annum
(*c*) Steam recip. (oil) ..... $440 \times 10^6$ ton/miles per annum
(*d*) Turbine (coal) ..... $431 \times 10^6$ ton/miles per annum
(*e*) Steam recip. (coal) ..... $424 \times 10^6$ ton/miles per annum

The following costs per annum are considered to be reasonable and are on a comparative basis:—

| Machinery. | Boiler and machinery repairs and survey. | Engine stores and water. | Engine-room staff wages and provisions. |
|---|---|---|---|
| | £ | £ | £ |
| (*a*) Diesel | 1400 | 625 | 2750 |
| (*b*) Turbine (oil) | 1300 | 474 | 2550 |
| (*c*) Steam recip. (oil) | 1100 | 500 | 2350 |
| (*d*) Turbine (coal) | 1350 | 475 | 3700 |
| (*e*) Steam recip. (coal) | 1150 | 500 | 3500 |

* N.E.C. Inst. From a paper entitled "Fuel Consumption and Maintenance Costs of Steam and Diesel-engined Vessels," by L. J. Le Mesurier (Member), and H. S. Humphreys.

As regards cost of bunkers, the fuel prices naturally vary according to trade routes and current market conditions. It is therefore only possible to make a comparison on the basis of fuel prices chosen to show a fair average of bunker prices ruling during the past few years. Certain routes may favor coal and others oil, and conclusions as to the best fuel to use can only be arrived at after consideration of the particular requirements of each case. On this basis, the following figures have been chosen for comparison:—

Furnace fuel oil.....35s. per ton.
Diesel fuel .....45s. per ton.
Coal .....20s. per ton.

The bunkers consumed at sea per annum would therefore cost as follows:

| Machinery. | Fuel lb./s.h.p./hr all purposes | Tons fuel consumed at sea per annum. | Cost per ton. | Cost for 300 days steaming per annum. |
|---|---|---|---|---|
| | | | s. | £ |
| (*a*) Diesel .. .. .. | 0·360 | 3,472 | 45 | 7,812 |
| (*b*) Turbine (oil) .. | 0·750 | 7,232 | 35 | 12,660 |
| (*c*) Steam recip. (oil) | 0·900 | 8,680 | 35 | 15,190 |
| (*d*) Turbine (coal) .. | 1·125 | 10,848 | 20 | 10,848 |
| (*e*) Steam recip. (coal) | 1·350 | 13,020 | 20 | 13,020 |

The cost per million ton/miles can therefore be summarized as follows:—

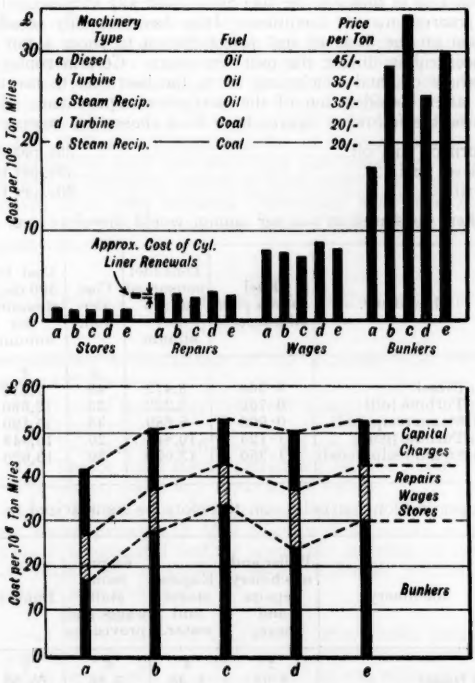
| Machinery. | Boiler and machinery repairs and survey. | Engine stores and water. | Engine room staff wages and provisions | Bunkers |
|---|---|---|---|---|
| | £ | £ | £ | £ |
| (*a*) Diesel .. .. .. | 3·03 | 1·35 | 5·96 | 16·90 |
| (*b*) Turbine (oil) .. | 2·92 | 1·06 | 5·70 | 28·40 |
| (*c*) Steam recip. (oil) | 2·50 | 1·13 | 5·35 | 34·42 |
| (*d*) Turbine (coal) .. | 3·13 | 1·10 | 8·58 | 25·30 |
| (*e*) Steam recip. (coal) | 2·71 | 1·18 | 8·25 | 30·70 |

These costs are shown diagrammatically in Figure 1.

In arriving at the above analysis of costs, the following points have been taken into consideration:—

*Engine-room Stores and Water.*—The principal item affecting this comparison is lubricating oil. Turbine machinery is the most economical in this respect; the consumption per day being approximately 3½ gallons for turbine, 5 gallons for steam reciprocating, and 12 gallons for Diesel machinery. On the other hand, more fresh water will be required for steam machinery. For Diesel machinery 1½ tons per day has been allowed for make-up feed and cooling water system, and for steam machinery 3 tons for make-up feed, any boiler water above these amounts being supplied by the evaporator.

*Engine-room Staff Wages and Provisions.*—The costs under this heading include the wages and provisions of the engine-room staff. An electrician has been included in the Diesel and turbine proposals, but not in the case of the steam reciprocating type. The higher scale of pay for motor ship engineers




FIGS. 1 AND 2.—RUNNING AND MAINTENANCE COSTS AND TOTAL COSTS.

has been included. The coal-fired vessels require six additional firemen and three trimmers, involving extra wages and provisions.

*Boiler, Machinery Repairs, and Survey.*—These costs are taken to include boiler repairs and cleaning, repairs to main and auxiliary machinery, superheater repairs, examinations and special survey of boilers, machinery and propeller shaft. The costs shown may be, of course, considerably reduced where time and regulations permit of some of the work being done by ship's staff. It may be mentioned that, in this type of vessel, repair costs are likley to be on a higher scale owing to the little time available in port for repairs and examinations and the necessity of frequently bringing in shore assistance.

Although cost of repairs to Diesel machinery has fallen considerably due to the gain in experience of the *personnel* in this type of machinery and improved design and facilities for repairs, the repair costs are still somewhat higher than for steam machinery. The costs will vary considerably not only with the type of machinery, but with the care and attention it receives.

Machinery examinations, apart from repairs, form an important proportion of this expense. The following is a list of examinations which may be considered an average for the type of machinery in question.

| | Reciprocating engines. | Turbines. | Diesel engines. |
|---|---|---|---|
| Boiler cleaning .. .. .. | ¼ year | ¼ year | ¼ year |
| Cylinders— | | | |
| H.p. .. .. .. .. .. | ½ ,, | 2 years | 1 to 1½ years |
| M.p. .. .. .. .. .. | ¾ ,, | 2 ,, | |
| L.p. .. .. .. .. .. | ⅞ ,, | 2 ,, | |
| Main bearings .. .. .. | 1 ,, | 1½ ,, | 1½ ,, |
| Connecting-rods— | | | |
| Top ends .. .. .. .. | ½ ,, | — | 1½ ,, |
| Bottom ends .. .. .. | ½ ,, | — | 1½ ,, |

Although from this list it would appear that Diesel machinery does not entail much more examination on the whole than other types, it must be remembered that the opening out of cylinders and withdrawal of pistons for examination is a more lengthy and arduous job than with a steam reciprocating engine. Fortunately, there has been considerable improvement in later designs of Diesel machinery to facilitate the dismantling and generally to improve the accessibility for examination and repairs. The removal of a cylinder head in a modern two-stroke engine with airless injection presents little more difficulty than in a steam reciprocating engine, although it must, of course, be remembered that there are generally more cylinders to be examined.

Cylinder liner wear has been the subject of a considerable amount of discussion and still remains an important technical problem. The actual commercial importance may be assessed by considering the liner renewals required in a normal eight-cylinder four-stroke engine of the power under consideration. Assuming that the rate of wear is about 0.005 inch per 1000 running hours, the liners will have a life of approximately 50,000 hours. During this period the fuel consumed by the engine will amount to about 24,000 tons. The relative cost of fuel and liners is as follows:—

| | £ |
|---|---|
| Cost of eight new liners, including fitting | 1,000 |
| Cost of fuel at 45s. per ton | 54,000 |

From these figures it will be seen that the cost of liner renewals amounts to less than 2 per cent of the cost of the fuel. If the liners cost even twice this amount, or if their life was only half as long, the expenditure under this heading would be still less than 5 per cent of the cost of the fuel or less than would be obtained by increasing the specific fuel consumption from, say, 0.36 pound to 0.38 pound per S.H.P. hour. Actually, improvements in several directions are serving to reduce still further the expenditure on liner renewals. The importance of carefully centrifuging the fuel for the removal of water and impurities is now generally recognized, but it is considered that further important advantages may be gained by avoiding, as far as possible, cylinder liner distortion and condensation of combustion products due to over-cooling. These results may be effected partly by consideration of design and partly by running engines at high jacket temperatures and with the least possible difference between inlet and outlet temperatures, so that causes for distortion are removed. A high rate of water circulation, the use of fresh or distilled water cooling, heating of liners and pistons before starting, and the avoidance of local hot spots which may limit the average cooling water temperature, are all points which, if attended to, will certainly help towards reducing maintenance costs due to liner wear.

Pistons require to be inspected at intervals of twelve to eighteen months, and it is not unusual to find that the top two rings have to be renewed due either to breakage of the rings, or on account of excessive up and down clearance. If the grooves are worn badly it may be necessary to skim them and fit oversize rings, in which case it is best to adopt a series of standard-dimension rings to which the grooves are adjusted. Another alternative which has given excellent results is to fit a wearing ring of Davey Robertson type, which enables replace rings to be fitted without interfering with the piston. While the cost of piston ring renewals is usually a very small one, the cost of withdrawal for examination and reconditioning may easily amount to as much as liner renewals if the work has to be carried out by shore labor, as is usually the case in tanker vessels. If, however, dismantling for examination is done by the ship's staff, the total expenditure on pistons forms an unimportant item.

No appreciable expenditure is necessary on exhaust or inlet valves provided that clean fuel is used. Exhaust valves should remain in service for at least 1200 hours' running without attention, and at the end of this period they should be in such a condition that they can be replaced after slight regrinding. If time is important, as in the case of tanker vessels, it is usually more convenient to keep a spare set of valves and boxes so that the used valves can be replaced without delay and reconditioned as opportunity occurs. In exceptional cases, where exhaust valves burn out rapidly, the trouble is almost invariably caused by dirt or solid impurities in the fuel which should be removed by efficient centrifuging.

Inlet valves and fuel injection pumps and valves require little or no attention, and do not appreciably influence the cost under this heading.

Running parts, such as main bearings, connecting-rods, top and bottom ends, cam shaft bearings, etc., require practically no attention. In exceptional cases, however, where salt water has had access to the crank chambers, heavy repair costs may be involved due to the development of corrosion on the bearing surfaces.

Fracture of cylinder covers and liners may occasionally occur due to local overheating caused by deposits. The most likely cause of deposits arises when sea-water cooling is employed, as during the vessel's passage up river or in confined water there is always the possibility of contamination of the cooling-water system with finely divided mineral matter which cannot be excluded either by filtration or settling. In parts of the system where the circulation is more or less stagnant, local overheating occurs which progressively increases with deposit formation and eventually results in fracture. In a closed system with fresh-water cooling, the same thing may occur unless special precautions are taken to insure clean soft water and to avoid any possible contamination from either sea water or lubricating oil. Having already mentioned the advisability of operating engines with the highest possible jacket temperatures, it is clearly advisable to use a closed system with a rapid rate of circulation and to employ distilled water which will also avoid any possible trouble with deposits.

Pistons may be cooled either by water or oil, but having in mind the necessity of introducing the cooling medium either through telescopic or "walking" pipes, there are advantages in using oil which keeps these moving parts in better order and removes any risk of contamination of the bearing oil in cases where the piston-cooling system is partly arranged in the crank chamber.

It is unnecessary to refer in much detail to repairs and maintenance costs of steam machinery. Boiler cleaning, boiler and superheater repairs and surveys are generally the most important items, and in an installation of the

size in question would amount to about £400 per annum, assuming that the bulk of this work is carried out by shore staff. In these circumstances the cost of this item may be two to three times the cost of liner renewals in a motor ship. Steam reciprocating engines require very few repairs and beyond the usual examinations and adjustments require little expense in maintenance and upkeep. Where superheat is employed it is to be expected that more attention will be necessary to various details, such as valves, glands, drains, superheat elements, etc., and also in the engine, the H.P. cylinder and piston valve chest liners will require reborings at intervals, and some additional expense in rings as compared with a non-superheated installation.

The repair costs for coal-burning steamships will be slightly higher than for oil burners, this being due to the extra cost of boiler repairs, renewing fire-bars, etc., and also due to the effects of uneven firing and cold air admitted to the furnace during firing which tends to cause unequal expansions and leakage at the tube ends.

The repair costs for turbines are generally higher than for steam reciprocating engines. Whereas in the latter cylinder covers, etc., can be quickly lifted by the ship's staff for examinations of pistons and valves, shore assistance is usually necessary to lift turbine casings to avoid delay. More attention is also required to the condensers and air pumps owing to the higher vacuum which must be maintained for the sake of efficiency. Extra upkeep of pumps, separators, and other devices required in a high-efficiency turbine installation has also to be provided for. Troubles due to erosion or corrosion of blading have been practically eliminated since suitable qualities of material such as manganese bronze, Monel metal, and special alloy steels have been adopted. Injection of paraffin into turbines has been found very beneficial, and not only keeps the blading clean, but also acts as a lubricant in the air and feed pumps. It also reduces the possibility of priming and prevents scale from adhering to the surfaces of boilers.

The problems connected with reduction gearing appear to have been completely solved, and it is not anticipated that in a modern installation any appreciable upkeep costs will be incurred in this part of the machinery.

*Capital Charges.*—Allowance for interest on capital, depreciation, and insurance forms one of the major charges in the running costs of a vessel. Although this is a matter which is not strictly within the scope of a paper dealing with fuel and maintenance costs, the authors indicate below the effect of this factor on the vessel already considered. These costs are considered to be reasonably accurate for comparison purposes, but, naturally, individual engine builders may, under stress of competition, be prepared to offer more favorable prices than those indicated, and the capital charges will thereby be proportionately reduced.

It will be observed that the initial charges and estimated cost per ton mile are calculated on the basis of 12½ per cent to cover all charges related to capital cost. The reciprocating steam machinery is assumed to be a highly efficient type with regenerative condenser, super-heat and two-stage feed heating, which will be necessary to secure an oil fuel consumption of 0.9 pound per S.H.P. per hour on which the results have been based. Allowance has been made for the extra cost of seatings for the Diesel machinery. It should also be pointed out that in all proposals 300 steaming days at sea have been allowed for, and no allowance has been made for delay which may possibly occur in vessels fitted with coal-fired boilers. Where such delays occur it will have the effect of reducing the ton miles per annum and would thereby increase the costs above those indicated.

| Machinery. | Cost of machinery. | Allowance taken at 12½ per cent. on cost of machinery. | Cost per million ton/miles per annum. |
|---|---|---|---|
| | £ | £ | £ |
| (*a*) Diesel.. .. .. | 52,000 | 6,500 | 14·10 |
| (*b*) Turbine (oil) .. | 46,000 | 5,750 | 12·90 |
| (*c*) Steam recip. (oil) | 36,000 | 4,500 | 10·22 |
| (*d*) Turbine (coal) .. | 45,000 | 5,625 | 13·03 |
| (*e*) Steam recip.(coal) | 35,000 | 4,375 | 10·32 |

*Summary of Costs for Various Types of Machinery.*

| | Repairs. | Stores. | Engine-room wages, &c. | Bunkers. | Machinery only, capital charges. | Total. |
|---|---|---|---|---|---|---|
| (*a*) *Diesel machinery* .. .. .. | £3·03 | £1·35 | £5·96 | £16·90 | £14·10 | £41·34 |
| Percentage costs .. .. .. | 7·3 | 3·2 | 14·4 | 41·0 | 34·1 | 100 |
| (*b*) *Turbine (oil)* .. .. .. .. | £2·92 | £1·06 | £5·70 | £28·40 | £12·90 | £50·98 |
| Percentage costs .. .. .. | 5·7 | 2·1 | 11·2 | 55·7 | 25·3 | 100 |
| (*c*) *Recip. (oil)* .. .. .. .. | £2·50 | £1·13 | £5·35 | £34·42 | £10·22 | £53·62 |
| Percentage costs .. .. .. | 4·7 | 2·1 | 10 | 64·1 | 19·1 | 100 |
| (*d*) *Turbine (coal)* .. .. .. .. | £3·13 | £1·10 | £8·58 | £25·20 | £13·03 | £51·04 |
| Percentage costs .. .. .. | 6·1 | 2·2 | 16·8 | 49·4 | 25·5 | 100 |
| (*e*) *Recip. (coal)* .. .. .. .. | £2·71 | £1·18 | £8·25 | £30·70 | £10·32 | £53·16 |
| Percentage costs .. .. .. | 5·1 | 2·2 | 15·5 | 57·8 | 19·4 | 100 |

The total and detailed costs are summarized in the table below, which shows the cost per 1 million ton miles under each heading, and also the percentage of these costs in relation to the total. These costs are shown diagrammatically in Figure 2.

### ADMINISTRATION AND PORT CHARGES.

Although these have not been taken into account, it may be mentioned that owing to the Diesel vessel's carrying more cargo than identically similar vessels with the same draught and displacement, but with other type of machinery, these charges will be proportionately less.

### CONCLUSIONS.

Fuel consumption is the most important factor affecting the relative running costs of vessels fitted with different types of machinery, the next most important factor being the capital cost. A comparatively small gain in fuel economy will generally prove far more important than considerable differences in relative repair costs or other factors which have been referred to. The cargo-carrying capacity may be greatly affected by the fuel consumption depending upon the trade route, bunkering conditions, and steaming radius, while these conditions will also similarly affect the actual fuel costs. It is therefore not intended by the authors that any broad conclusions as to the most suitable type of machinery for all classes of vessels should be drawn from the analyses given above. Each particular case must be dealt with on its own merits. It should, however, be noted that in the case of Diesel machinery this important factor of fuel consumption can be predicted with no appreciable margin for error, but with steam machinery an allowance must be made to cover variations in performance due to the human element, which so largely controls the running of this type of machinery, and also for variation in performance caused by the state of boiler surfaces and conditions of superheat, feed temperature, and vacuum.

It is hoped that the brief reference made to different types of propelling machinery may encourage users to give the results of their experiences, particularly in regard to fuel consumption and maintenance. As, however, machinery type and not hull performance is in question, it is considered essential that where fuel consumption is given it should be based on the actual specific fuel consumptions obtained from a carefully ascertained power output. Fuel coefficients which take into account both machinery and hull performance are of very little interest in the subject under discussion.—"The Engineer," February 22, 1935.

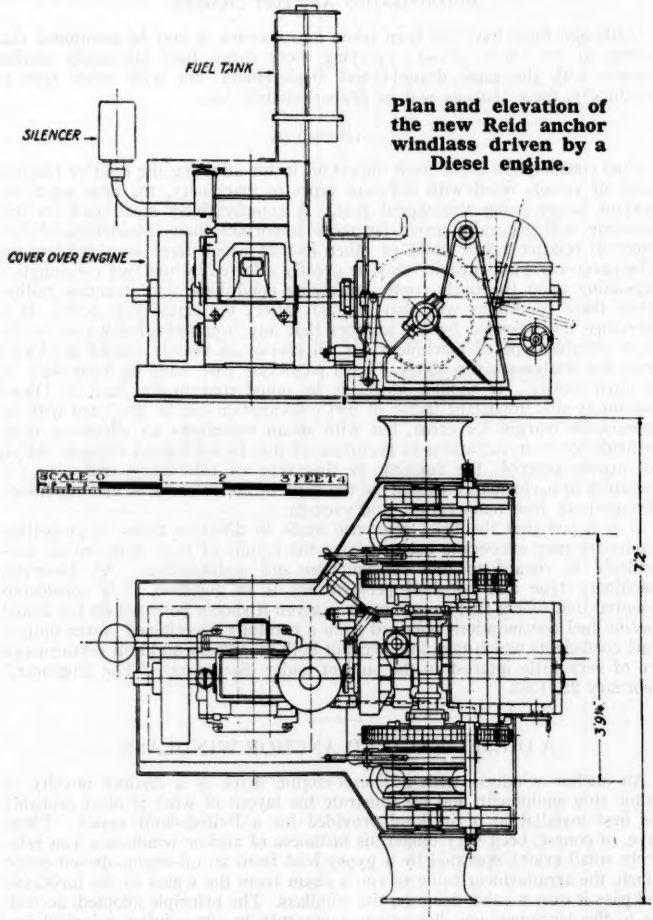
---

## A DIESEL-ENGINED ANCHOR WINDLASS.

An anchor windlass with a Diesel-engine drive is a distinct novelty in motor ship equipment, and we illustrate the layout of what is most probably the first installation of its kind provided for a British-built vessel. There have, of course, been very numerous instances of anchor windlasses (on relatively small craft) operated by a gypsy lead from an oil-engine-driven cargo winch, the arrangement being to run a chain from the winch to the forecastle and pass it over a cable drum on the windlass. The principle adopted, according to the accompanying illustration, represents, in our opinion, a logical improvement on earlier methods.

The windlass to which the plans refer is installed, with certain small modifications, on the motor coaster *Camroux I.* A Ruston Lister two-cylinder Diesel engine forms the power unit. It develops 10 B.H.P. at 800 R.P.M.,

and the windlass operates a 15/16-inch anchor chain. Two-speed gearing is fitted, and in the event of an overload on the engine the high-gear ratio is immediately engaged and there is a direct pull of 5 tons on the cable. When the overload has been overcome the low gear is engaged and the lifting speed is correspondingly increased, the pull exerted being 2¼ tons.




**Plan and elevation of the new Reid anchor windlass driven by a Diesel engine.**

Two warping drums are fitted and with these the two-speed gear allows a pull of 4 tons with the slow-speed mechanism engaged, the high-speed gear giving a pull of 1¾ tons. Between the engine and the windlass is a friction

clutch. Worm gearing is provided on the windlass gearcase, so that when the engine is declutched the load is held in any position. The windlass was built by Messrs. Thomas Reid and Sons (Paisley), Ltd., and a similar installation has been supplied to *Camroux II*, which has just been placed in commission. We are informed that the performance of the windlass on the first ship has proved satisfactory.—"British Motorship," February, 1935.

## PROTECTION AGAINST GAS BOMBARDMENT.*

By M. Du-Plat-Taylor, M. Inst. C.E.

The use of toxic and asphyxiating gases in warfare is by no means new. In 1275 an Arab writer, Hassan Abramanach, described the fabrication of poisonous gas from arsenic and opium; and in 1650 Glauber, the German chemist, prepared a formula for the manufacture of hand grenades containing a mixture of turpentine (probably rosin), nitric acid, and gunpowder, designed to suffocate the enemy. Sulphur fumes were also employed from time to time for this purpose, and Lord Dundonald in 1855 made a proposal for the use of charcoal and sulphur for filling shells for use in the siege of Sebastopol; but this was not approved of by Lord Palmerston. These facts were not made public until the publication of the Panmure Papers in 1908.

No further attempts appear to have been made to develop this form of warfare until the great German gas offensive was devised in 1915 by Professor Nernst, of the Berlin University, and Professor Haber, Director of the Emperor William Institute at Dahlem.

The first gas attack was released on April 22nd, 1915, against the Ypres Salient, and cost the lives of 5000 of the Allied troops.

To illustrate the concentration of such attacks, the Austrian gas attack of June 29th, 1916, at St. Michele del Carso may be described. In this attack 6000 cylinders of liquid chlorine, each of 110-pound weight, were employed on a front of 6 kilometers, or one cylinder per meter of front. The valves of all the 6000 cylinders were opened simultaneously in a favorable wind, and the resulting heavy cloud of chlorine gas descending upon the Italian trenches destroyed 8000 men.

Since 1918 gas warfare has been perfected, some hundreds of gases having been investigated, and the immense improvement in air transport has rendered possible the discharge over enemy cities of quantities of gas immensely larger than those possible during the war.

We have it on the authority of Marshal Pétain that, in January, 1934, Germany possessed 375 aircraft, each capable of carrying a load of 1 metric ton of gas bombs to a distance of 500 kiloms. (310 miles) and returning to its base, and thirty larger machines capable together of carrying 50 tons to a distance of 1000 kiloms. (621 miles). Italy possessed at that time 420 machines capable together of carrying 300 tons for a distance of 310 miles, and enough larger machines to carry 50 tons 621 miles.

The distance from the nearest point on the German frontier to Paris is 200 miles as the crow flies, and to London 350 miles.

The total weight of projectiles discharged upon Paris by aerial and other bombardments in the eleven months ended November, 1918, was 11 tons, or 1 ton per month; whereas it would now be possible to discharge over 50 tons in one day, assuming that only half the available machines were used and only one-quarter of the invading aeroplanes escaped destruction on the way.

* Based upon the papers on "The Means of Defense Against Attacks by War Gas" and "Defense by Isolating Chambers and Shelters," by Monsieur George F. Jaubert; and "Air Filtering Appliances in Gas Warfare," by Monsieur Louis Bergé, read before the Société des Ingénieurs Civils de France, 1934.

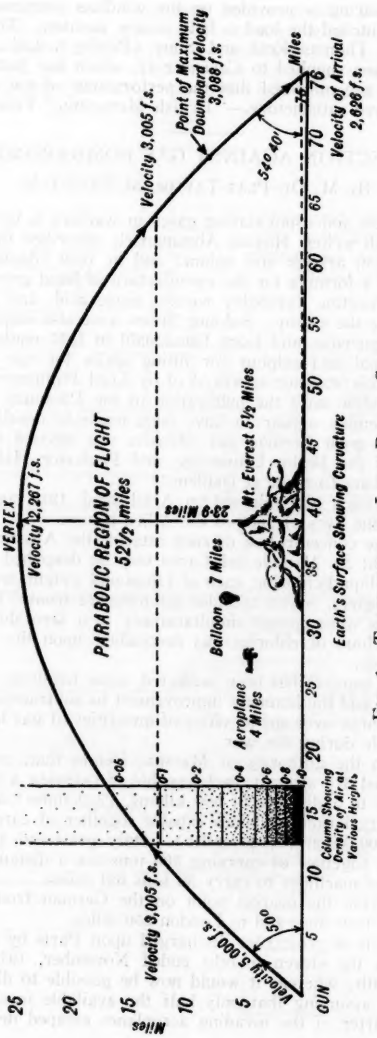



FIG. 1.—TRAJECTORY OF LONG RANGE SHELL.

There is also the question of land bombardment. On March 23rd, 1918, Paris experienced for the first time a bombardment with high-explosive shells, which had been fired from a gun mounted in the forest of St. Gobain on the German front at the unprecedented range of 75 miles. These shells were 8.28 inches in diameter, weighing 330 pounds, and fitted with long hollow ogival heads. It has been calculated that the muzzle velocity of the gun was 5000 foot-seconds, or nearly 1 mile per second, and that the velocity of arrival of the shell was 2626 feet per second. The velocity of arrival of the shell being over double that of sound in air, it was impossible to hear it coming. In the course of its flight (see Figure 1) the shell passed into the stratosphere, the highest point of its trajectory being 24 miles above the earth's surface, or four times the height of Mount Everest.

There is no reason, other than difficulties of manufacture, why guns should not be constructed for a much higher muzzle velocity even than this, to throw shells to a much greater distance with considerable accuracy.

Three-quarters or more of the trajectory would be practically in vacuo, where no disturbing influences would deflect the path of the shell.

There is, however, a great disparity of cost between that of the use of such guns and of the use of aircraft for conveying like quantities of gases, in favor of the aeroplane.

It is therefore likely that guns will only be employed on account of the element of surprise, and that the greater part of gas bombardments in future will be carried out by the medium of air transport, probably with machines constructed for purposes of civil aviation.

War gases may be divided into—

(1) "Fugitive" gases, which are gaseous at atmospheric pressure and at ordinary temperatures, such as chlorine, phosgene, carbon monoxide, and nitrous gases.

(2) Persistent gases, such as Yperite (mustard gas), Lewisite, and arsenical dust clouds, which are six times as toxic as phosgene.

The action of mustard gas is on the skin, and therefore no mask is effective against it. The only protection is a completely protective airtight suit of rubber-impregnated clothing in combination with an air-filtering mask or oxygen regenerative apparatus, or else resort to an airtight shelter.

The other gases mentioned above act upon the throat, nose, and lungs, and protection can be obtained by filter masks or oxygen regenerative apparatus alone.

The latest form of gas mask is a charcoal filter, either in combination with various chemical substances or alone. The objection to a gas mask of this nature is that in some strong concentrations of gas there is not enough oxygen to maintain life, and when the chemical substances of the gas are filtered out the wearer would still die of suffocation.

Portable oxygen inhalers have therefore been adopted, of which there are many patterns. These form complete protection against all the gases which act upon the respiratory system. The type adopted in France is known as the Oxylithe-Lemoine system, and consists of a knapsack containing a mixing chamber which is provided with a connection for an oxygen cartridge or sparklet, which can be attached to the apparatus by the wearer and replaced by a new one when it is exhausted. The cartridge contains granulated oxylith.

### COLLECTIVE SHELTERS AGAINST GAS ATTACK.

In principle these shelters are a protection against the three dangers, namely, the explosion of shell, fire, and asphyxiation. A shelter for the purpose of protection against (1) and (2) requires to be at a considerable depth below ground level, and should be provided with a roof of considerable thickness of reinforced concrete.

With regard to the third danger, that of asphyxiation, the shelter must be absolutely air-tight.

Experiments have been made with various types of door sealing apparatus, and have shown that there is no difficulty in meeting this requirement, so far as the entrance and exit to the shelter is concerned. The most effective system is that which depends upon a pneumatic bolster joint, which can be inflated when the door is closed.

This type of joint is shown in Figure 2. The left-hand view shows a section of the joint with the door open, *a* and *b* representing the fixed part of the door or jamb, of which *b* is that portion which is on the opening side and is cut away to allow the door itself to close or open; *c* is the edge of the door which forms the air-tight joint. The next view shows the door closed with the joint not inflated, and the last the door in the same position with the joint inflated.

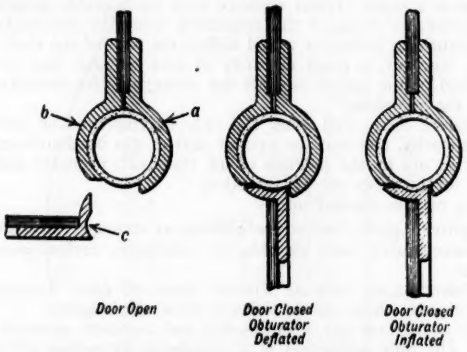



FIG 2.—PNEUMATIC BOLSTER DOOR JOINT.

The bulge produced by the rubber tube which projects into the recessed part of the door also keeps the door closed unless considerable force is exercised.

In other systems the air-tightness is assured by compression from the outside of some jointing material, which may be rubber, copper, tallowed plait, flax, etc. This compression is effected by some mechanical method, which mush be so arranged that it can be operated rapidly.

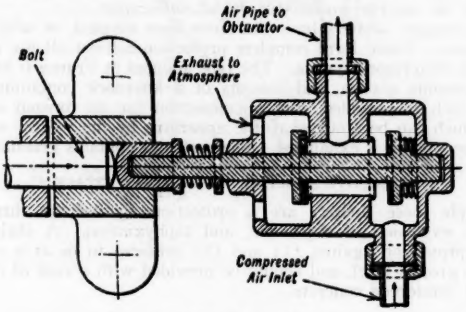



FIG. 3.—DOOR-LOCK VALVES.

With the pneumatic joint an arrangement, shown in Figure 3, can be provided, by means of which the inflation is instantaneously and automatically effected by the movement of the bolt of the door lock. The opening and closing is done in the same manner as in an ordinary door and the turning of the bolt handle for locking opens a valve and instantaneously inflates the obturator by the admission of compressed air from an air bottle. The opposite action of unbolting the door disconnects the obturator from the compressed air supply and opens it to the atmosphere, so that it immediately becomes deflated.

In the event of the failure of the compressed air supply provision is made whereby the obturator can be inflated by a few strokes of an air pump.

Two doors of this type (the Payen-Gip system) installed in a gas shelter in the sub-basement of one of the large Government offices in Paris are shown in Figure 4. A small bottle of compressed air is seen between the two doors mounted on a board on the wall.

As only a small quantity of compressed air is required for the necessary amount of inflation of the obturator, it might easily be arranged for the locking bolt to operate a piston or plunger so as to furnish the required amount of air when the bolt is shot.

### AIR SUPPLY AND VENTILATION OF SHELTERS.

There are two methods of assuring the proper ventilation of shelters: (1) the open cycle system, by which air drawn from the outside of the shelter is passed through large fixed filters before delivery into the shelter and the vitiated air is passed back to the atmosphere by fans; and (2) the closed cycle system, by which the air in the shelter is filtered to remove waste products and regenerated by the use of oxygen in cylinders or oxylith regenerators.

The second system is that employed in submarines.

Approximately 130 grams of oxygen is required for each person per hour; and, as a rough test for air in an enclosed space, a lighted candle is extinguished in an atmosphere containing less than 16.2 per cent of oxygen, and a match cannot be lit in an atmosphere containing less than 17.5 per cent of oxygen.

*The Open Cycle System.*—This consists in the simple filtration of the exterior air drawn from as great a height as possible above ground level by means of an electric fan (and in case of failure of the current by a pedal-operated fan). This exterior air is first of all filtered in an anti-arsenical filter, the object of which is to retain all the gases which may exist in corpuscular form in the air drawn in. The air is then passed through a carbon filter in which all the heavy gases, chlorine, phosgene, etc., are arrested. The only gas which can wholly or partly escape this purification is extremely light gas, such as carbonic oxide or hydro-cyanide gas. A carbonic oxide detector is placed on the outside of the second filter of the system. Automatic valves are so arranged as to enable the filters to be quickly put out of the circuit and to seal the intake of air hermetically. Consequently, if the detector indicates the presence in the filtered air of toxic acid, or if the manometer in the intake indicates an unexpected obstruction in the air supply pipe which might be caused, for instance, by the destruction of the outer part of the intake pipe by a shell, it must be possible to change over instantly to the closed cycle air system.

*The Closed Cycle System.*—There are several types of apparatus for closed cycle working. The used air is decarbonized by alkaline solutions or anhydrous products. The complement of oxygen is made up by providing this

in a compressed form in steel cylinders or by generating it from oxylith (alkaline peroxide). A kilogram of oxylith produces approximately 150 liters of oxygen.

### DESIGN OF SHELTERS.

As already stated, the shelters consist of underground chambers completely protected from bombardment, if possible, but in any case air-tight, and they must therefore be provided with air-tight doors. In addition, it is better that there should be a slightly higher air pressure within the shelters, which would tend to prevent any exterior gas from penetrating, either by accidental cracks or imperfections in the obturator.

Air-tightness of masonry shelters is difficult to ensure, and it is in this respect that a metallic chamber is a considerable advantage. Neverthless, it is almost impossible to provide a metallic chamber to hold more than a hundred persons. For larger numbers it is, therefore, necessary to adopt some other form of construction.

Reinforced concrete appears to be the most satisfactory from the point of view that it can be further rendered impervious to gas by a coating of tar or some form of paint. It is necessary to take steps to prevent the sudden erruption of a crowd in an underground shelter as this might involve a cloud of gas entering. To prevent this, shelters are provided with air locks so arranged that the inner and outer doors cannot be opened at the same time.

The position of the staircase leading down to the shelter requires to be carefully considered, both from the point of view of admitting gas and from the point of view of the entrance being demolished or blocked by bombardment, so permanently imprisoning those in the shelter. It is for this reason considered better that the entrance should be from a basement or sub-basement of some building, and that there should be two entrances as far apart as possible to every large shelter.

As it may be necessary in a continuous bombardment to provide means for a prolonged stay in the shelter, chairs, tables, hammocks for sleeping, electric cooking arrangements for warming up previously prepared food, water supply and water closets must be provided.

The evacuation of soiled water is arranged by means of a force pump, by which it is pumped into the sewers, usually at a higher level than the underground shelter.

To determine the size of shelter, the volume required per person is obtained by the following formula:—

$$T = \frac{V}{N} \times \frac{3}{4}$$

T being the time in hours during which N occupants can remain in a shelter of volume V cubic meters without the necessity of eliminating the carbonic acid.

Resolving this equation, we get:

$$V = \frac{4\,NT}{3}$$

and if N and T are unity, we find:

$$V = \frac{4}{3} = 1333 \text{ liters}$$

which is the quantity of air required for one person for one hour.

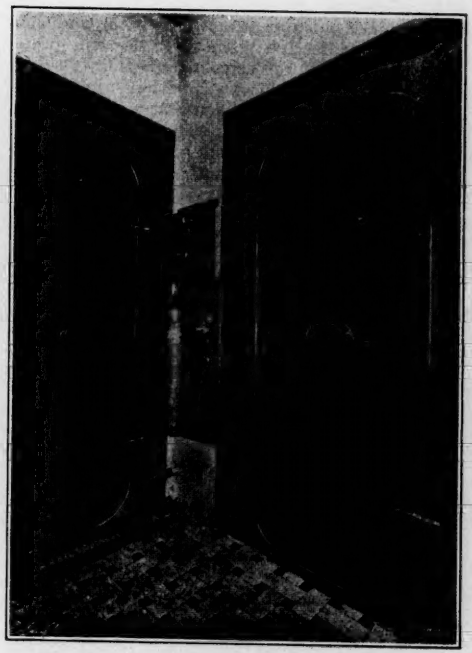


FIG. 4.—AIR-TIGHT DOORS.

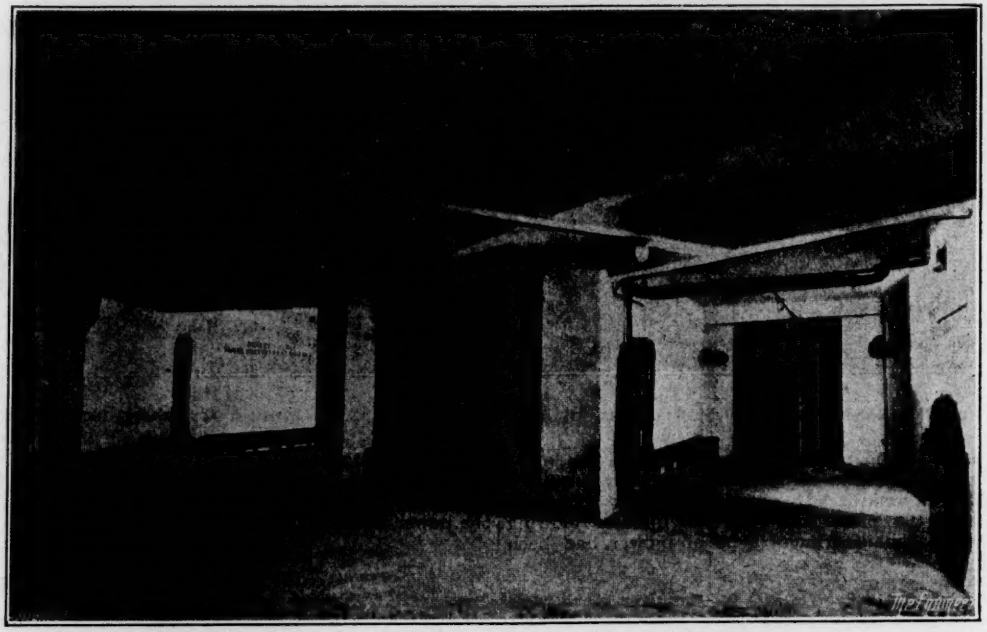


FIG. 6.—UNDERGROUND SHELTER UNDER A GOVERNMENT BUILDING.

FIG. 7.—FAN FOR CLEARING OUTSIDE GAS.

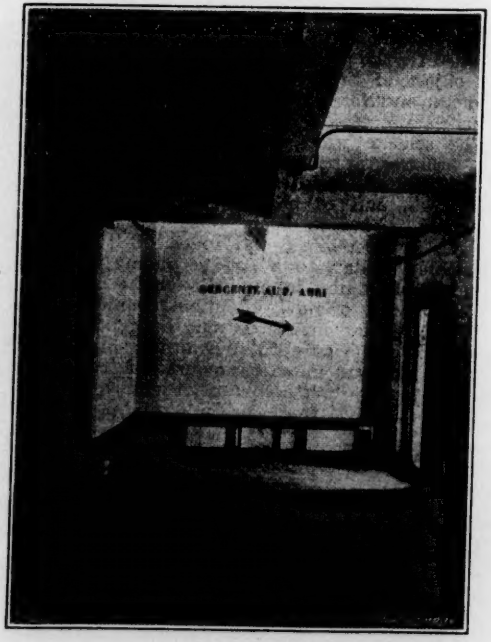


FIG. 9.—ENTRANCE TO LOWER FLOOR OF UNDERGROUND SHELTER.

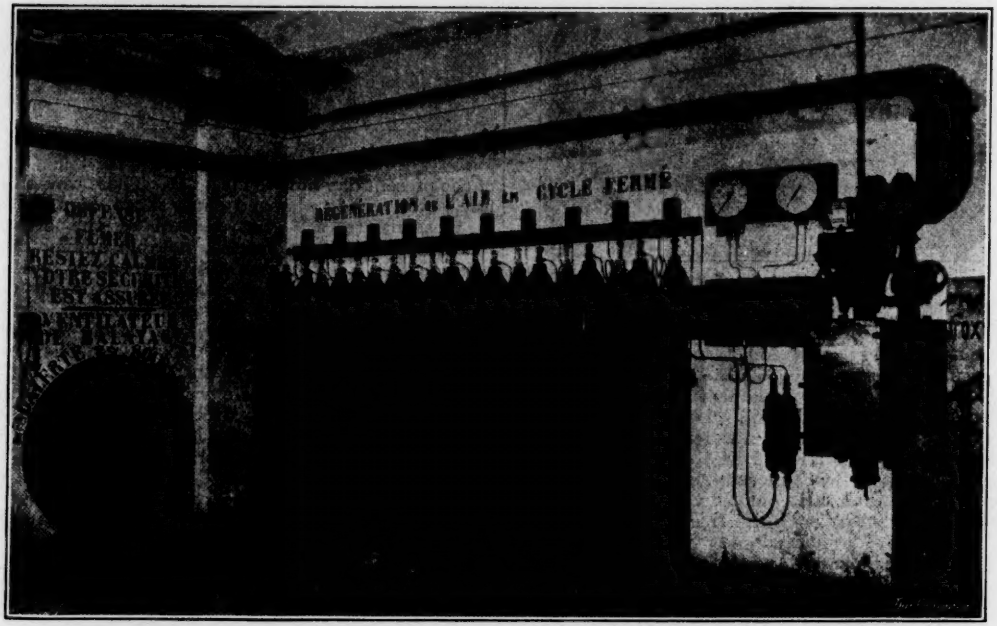



FIG. 8.—CLOSED CYCLE AIR REGENERATOR.

The German formula:

$$T = 0.48 \frac{V}{N}$$

gives a higher result, namely 2084 liters, and it is safe to allow a circulation of 2000 liters of filtered air per hour per head on the open-cycle system for small shelters, and, say, 1500 liters per hour per head for large shelters.

As regards the floor area required, this is largely a question of comfort, but a minimum of 1 square meter per person should be observed.

In Figure 5 is shown a typical shelter designed by Messrs. Sinrapt and Brice for a block of flats near the Bois de Boulogne, and placed under a little garden which completely covers the shelter and serves as a protection for it.

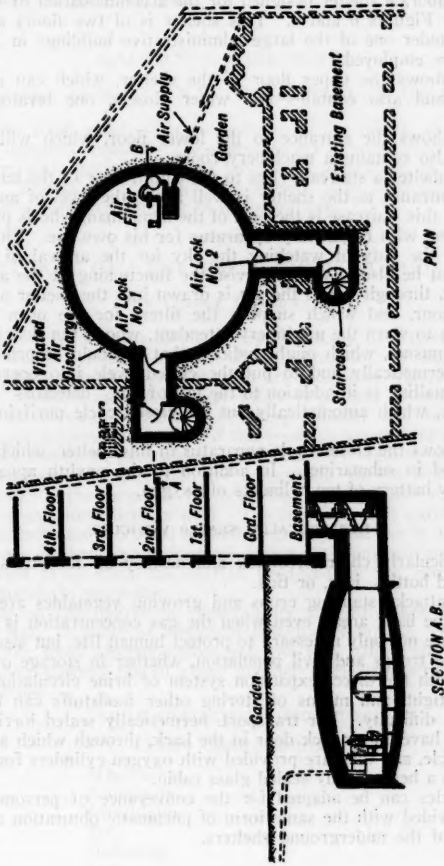



FIG. 5.—UNDERGROUND SHELTER.

It will be observed that the shelter is circular, constructed of reinforced concrete with a domed roof and inverted floor. It has two separate means of access through airlocks from different parts of the main building, and is provided with an air filter and fan.

When the entrance to a shelter is in the basement or sub-basement of a building, it is necessary to provide some means of clearing the basement or sub-basement of gas when the alarm is over and before the inmates of the underground shelter are released.

This necessity arises from the fact that the gases used are heavier than air and, therefore, naturally collect at the lowest point. This is provided for by special fans, one of which, with a capacity of 30,000 cubic meters an hour, is shown in Figure 7.

A more elaborate shelter designed for the accommodation of 400 people is illustrated in Figures 6 and 9. This shelter is of two floors and has been constructed under one of the large administrative buildings in Paris, where 350 people are employed.

Figure 6 shows the upper floor of the shelter, which can accommodate 200 people, and also contains two water closets, one lavatory, and fire services.

Figure 9 shows the entrance to the lower floor, which will shelter 200 people, and also contains a machinery room.

From this shelter a staircase rises to the eighth floor of the building above, so that the entrance to the shelter is well above the level of any gas cloud. At the top of this staircase is the post of the signalman, who is provided with a telephone and with respiratory apparatus for his own use. This signalman has not only the duty of watching the sky for the arrival of bombarding aeroplanes, but he also has to supervise the functioning of the air locks and the ventilator, through which the air is drawn into the shelter at 1500 cubic meters per hour, and which supplies the filters for the open cycle. The signalman has to warn the machinery attendant, who is ten floors below him, of anything unusual, which might indicate that it would be prudent to close the shelter hermetically and to put the closed cycle into operation. This system of signalling is in addition to the use of gas "detectors" of the Gip-Malsalez type, which automatically put the closed cycle purifying apparatus into action.

Figure 8 shows the closed cycle apparatus in this shelter, which is identical with that used in submarines. In addition to the oxylith apparatus, there is an auxiliary battery of ten cylinders of oxygen.

### HERMETICALLY SEALED VEHICLES.

Gases, particularly chlorine, attack and destroy all foodstuffs other than those in sealed bottles, jars, or tins.

In all gas attacks standing crops and growing vegetables are completely destroyed in the back areas, even when the gas concentration is very slight.

It is therefore not only necessary to protect human life, but also the supply of food for the troops and civil population, whether in storage or in transit. Cold stores with the direct expansion system or brine circulation system in pipes are gastight, and means of storing other foodstuffs can be provided without much difficulty. For transport, hermetically sealed lorries are provided. These have an air lock door in the back, through which a person can enter the vehicle, and they are provided with oxygen cylinders for the driver, who is also in a hermetically sealed glass cabin.

These vehicles can be adapted for the conveyance of persons, and their doors are provided with the same form of pneumatic obturation as that used in the doors of the underground shelters.

Finally, a certain *personnel* is required to be on duty in air raids for the purpose of succoring the injured and gassed people in the streets. For this service these men are provided with a complete suit of air-tight rubber clothing and a respiratory apparatus, either consisting of a mere filter like an ordinary gas mask or with an oxygen-generating apparatus.

Though the danger of aerial gas bombardment is nothing like so serious in this country as it is in France, yet it is a matter which deserves, and no doubt is receiving, the most serious consideration.

The writer is indebted to the authors of the three papers mentioned and to the Council of the Société des Ingénieurs Civils de France for permission to make extracts from those papers and reproduce some of the illustrations, and to the Royal Artillery Institution for permission to reproduce Figure 1.—"The Engineer," February 8, 1935.

## GALVANIC CORROSION.

By the Secretary of the A.S.N.E. (Commander C. S. Gillette, U.S.N).

Two articles from widely different sources on the subject of galvanic corrosion have appeared recently. These articles are of more than usual interest in connection with this subject and have been abstracted in the following paragraphs. The tables from the two sources have been combined in the discussion for greater convenience in study and use.

## ABSTRACT OF "THE PROBLEM OF CORROSION."

By George F. Crouch.

Corrosion is defined as the eating or wasting away of a metal by a chemical charge which produces oxides, salts, hydroxides, or similar chemical compounds of the metals. Some of them are soluble in water, others insoluble. If the products are soluble and water is present in excess, the metal appears to waste away, gradually becoming smaller and smaller, until it finally disappears completely. But, if the products are insoluble, like rust on iron and steel, the metal part which is attacked may seem to increase in size.

Two general types of corrosion are recognized. In the first type there is a direct attack on the metal by the corroding agent, which may be oxygen, any corrosive salt, any alkali or acid. The second type is galvanic corrosion. As the name indicates, electrical as well as chemical action is involved. What really happens is that direct chemical action is intensified and localized by the generation of an electrical current produced by the immersion of two dissimilar metals in sea water.

Depending on the degree of dissimilarity the difference in potential is greater or less. A table of electrical polarities follows. The first named element is the most electropositive and the last named the most electronegative. Any element placed above another is electropositive with respect to the lower one.

TABLE OF ELECTRICAL POLARITIES.

(From Electropositive.)

Magnesium
Aluminum
Duralumin
Zinc
Cadmium
Iron

Chromium Iron (Active)
Chromium Nickel Iron (Active)
Solder
Tin
Bronze
Monel Metal
Copper
Chromium Iron (Passive)
Chromium Nickel Iron (Passive)
Silver
Gold
Hydrogen
Carbon
Tungsten
Vanadium
Chromium
Chlorine
Sulphur
Oxygen

(To Electronegative.)

It will be noticed that chromium iron and chromium nickel iron have two positions in the table, depending on whether they are in a so-called "passive" or "active" state. Unfortunately, the "active" state is the more stable one and these alloyed irons or steels tend to revert to the active state quite unexpectedly.

When an electrical cell is formed by two dissimilar metals and sea water, anything which increases the resistance of the electrical circuit such as increasing the length of the path (separation of the metals) or decreasing the area of the path (small amount of surface exposed) reduces the current and the consequent corrosion. When two metals are actually in contact and are exposed to sea water, the outside circuit for the current is completed through the metals themselves. This path, being short and of large area, is of low resistance and, with the exposed surfaces actually touching each other in the water, produces the most dangerous type of galvanic corrosion, for the current is then a maximum. The passage of galvanic current through the water always liberates a chemically corroding agent at the electropositive metal where it immediately attacks the metal with a greatly intensified chemical action. The electronegative metal, on the other hand, is really chemically protected by the galvanic current for the noncorrosive elements in the water are liberated at this metal.

Again referring to the table, the greater the difference in the table between the metals in contact, the greater the effect on corrosion. In general, metals which are grouped together in the table can be associated in sea water without any great danger if the surfaces exposed to the action of the water are moderate in area. The reason for this is that the voltage is low and consequent current small. The intensity of galvanic corrosion is a function of current, not voltage.

It is particularly dangerous to have a large area of electronegative metal in contact with a small area of an electropositive one, for the electropositive metal will be corroded with an accelerated intensity. It might be considered that the whole area of the electronegative metal contributes to the active corrosion of the small area of the electropositive metal. For instance, iron rivets in brass or monel metal plates eat away with extreme rapidity.—"Yachting," February, 1935.

TABLE I.

## ELABORATION OF TABLE IN ARTICLE BY J. W. WILLSTROP "THE E. M. F. BETWEEN METALS IN SEAWATER"

THE ENGINEER, JANUARY 25, 1935.

| No. | Type | Condition | C % | Mn % | Si % | Cr Per cent | Ni Per cent | Al Per cent | Mg Per cent | Cu Per cent | Fe Per cent | Zn Per cent | Potential against Calomel Electric Volts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DTD 57A | Austenitic | Cold rolled strip | Max. .20 | Max. 1.00 | Min. .50 | Min. 12.0 | Min. 6.0 | ... | ... | ... | ... | ... | .15 |
| 57B, 166 | 18 Cr–8 Ni | | | | | | | | | | | | .25 |
| DTD 428, | Austenitic | Annealed strip | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .15 |
| 144, 171 | 18 Cr–8 Ni | | .20 | 1.00 | .50 | 12.0 | 6.0 | ... | ... | ... | ... | ... | .25 |
| | Monel metal | ... | ... | ... | ... | ... | about 67 | ... | ... | about 30 | about 3 | ... | .18 |
| | Al. Bronze | ... | ... | ... | ... | ... | ... | about 9.0 | ... | about 88.0 | Fe about 3.0 | ... | .26 |
| B–2 | Gun metal | ... | ... | ... | ... | ... | ... | ... | ... | about 88 | Sn about 9.0 | about 3 | .21 |
| 3. B. 12 | Brass | ... | ... | ... | ... | ... | ... | ... | ... | about 60 | Sn about 1.0 | about 39 | .27 |
| S 80 | Two score Stainless | ... | ... | ... | ... | about 8.0 | about 2.0 | ... | ... | ... | ... | ... | .30 .40 |
| DTD 60A | 18% Cr steel | ... | .20 | 1.00 | Max. .60 | 16.0–20.0 | Min. 1.0 | ... | ... | ... | ... | ... | .30 .40 |
| DTD 10S | 13% Cr steel | Tubes | .15 | ... | .50 | Min. 12.0 | Max. 1.0 | ... | ... | ... | ... | ... | .45 |
| DTD 46A | 13% Cr steel | Strip | .12–.20 | ... | .50 | 12.0 | 1.0 | ... | ... | ... | ... | ... | .58 |
| DTD 54A | Structural Cr–Ni steel | Strip | .25–.35 | .45–.70 | ... .30 | .50— 1.50 | 3.0— 5.0 | ... | ... | ... | ... | ... | ... .62 |
| | Duralumin | Heat-treated and aged or cold- | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .65 |
| | | | | about | Max. | | | Min. | about | about | Max. | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cr–Ni steel | | .35 | .70 | .30 | 1.50 | 5.0 | ... | ... | ... | ... | ... | ... | .62 |
| | Duralumin | Heat-treated and aged | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .65 |
| 28 | Duralumin | or cold-worked | ... | about .75 | Max. .50 | ... | ... | Min. 92.0 | about .5 | about 4.0 | Max. .50 | ... | ... | .69 |
| | Duralumin | Soft | ... | about .75 | Max. .50 | ... | ... | Min. 92.0 | about .5 | about 4.0 | Max. .50 | ... | ... | .72 |
| S4 | Duralumin | High tensile | .50 | 1.75 | .30 | ... | ... | ... | ... | ... | ... | ... | ... | .72 |
| DTD 128 | C-Mn steel | strip | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .72 |
| | Royce-royce alloy sheet | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .73 |
| | S-2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .73 |
| | Duralumin | plate | | about .75 | Max. .50 | ... | ... | Min. 92.0 | about .5 | about 4.0 | Max. .5 | ... | ... | .76 |
| | S-6, S21 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .76 |
| DTD 12 | Low carbon steel strip | ... | .04—.12 | .20—.50 | Max. .20 | ... | ... | P-04 S-04 | ... | ... | ... | ... | ... | .79 |
| DTD 25 | Aluminium silicon | ... | ... | Max. .50 | 10.0—14.0 | ... | Impurities total .1 | Impurities total .1 max | ... | ... | Max. .75 | ... | ... | .81 |
| MG 7 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .81 |
| | Birmabright | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .82 |
| | Aluminium | ... | ... | ... | ... | ... | ... | commercially pure | ... | ... | ... | ... | ... | .82 |
| | Cadmium | (plating) | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .82 |
| | Zinc | (plating) | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1.13 |
| DTD 88 | Mg alloy | ... | ... | Max. 1.0 | ... | ... | ... | Max. 10.0 | Remainder | ... | ... | Max. 1.5 | ... | 1.59 |

## ABSTRACT OF "THE E.M.F. BETWEEN METALS IN SEAWATER."

By J. W. WILLSTROP.

If any two dissimilar metals immersed in seawater are connected together by actual contact with each other or by a third conducting material, there will be a flow of current from one metal to the other and this will be accompanied by solution or corrosion of the negative metal. The tendency for this is dependent on the potential difference between the metals when immersed in seawater.

In an attempt to evaluate this voltage for different metals, potential differences were measured between the mercury of a normal calomel half cell and the metal under consideration immersed in seawater. The seawater was kept at a temperature of 25 degrees C. (77 degrees F.) and was not stirred.

The results obtained are given in Table I. In all cases the potential of the metal under test was negative to that of the calomel electrode, hence, in comparing any two metals, the metal giving the higher value will be negative to the other, and will tend to corrode more rapidly under galvanic action in seawater.

With some alloys, particularly stainless steels of the 18-8 type, a steady potential was not attained, but seemed to fluctuate about a value of 0.20 volt. this may be due to periodic changes in passivity.

(*Note*:—The table has been amplified over that appearing in "The Engineer" in that the condition and chemical composition of the various metals has been added, as nearly as available information has permitted).—"The Engineer" (British), January 25, 1935.

---

## DISCUSSION.

By THE SECRETARY.

The article by MR. CROUCH is most illuminating and clear. His table is lacking in usefulness only in that it does not evaluate the corrosion characteristics of the various metals, merely stating their relative position.

MR. WILLSTROP'S article attempts to evaluate, but his list is not so complete as that of Mr. Crouch. Below is given a table combining both the tables of Messrs. Crouch and Willstrop. Where the actual potential values of Mr. Crouch's metals are not known, they may be estimated from their postion in the combination table:

TABLE OF ELECTRICAL POLARITIES.

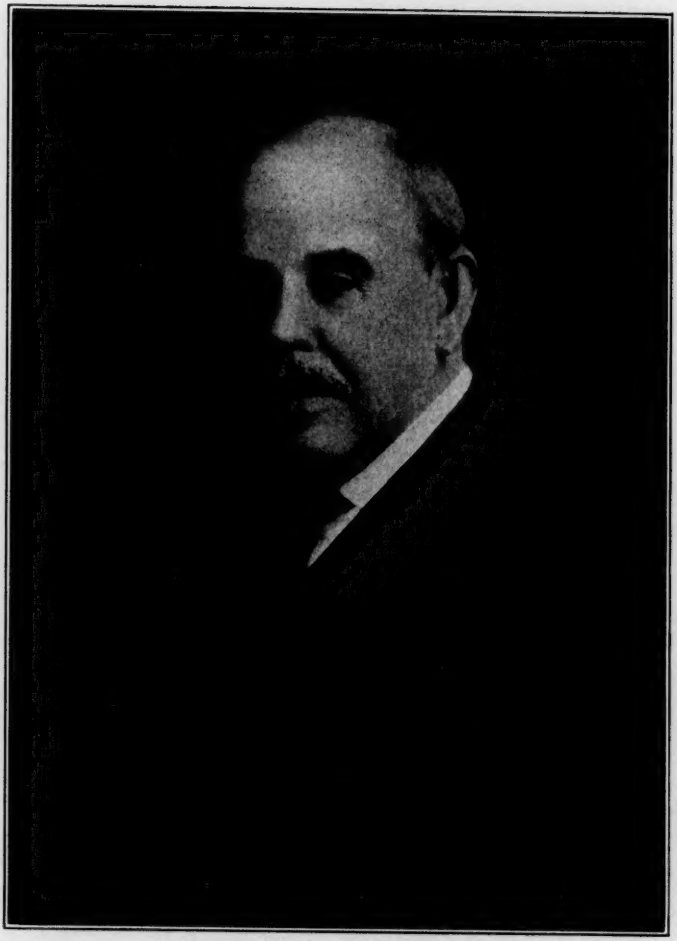
| (From Electropositive) | Potential Against Calomel Electrode Volts |
|---|---|
| Magnesium Alloy | 1.59 |
| Zinc | 1.13 |
| Cadmium | 0.82 |
| Aluminum | 0.82 |
| Birmabright | 0.82 |
| Aluminum Silicon | 0.81 |
| Low Carbon Steel Strip | 0.79 |
| Duralumin (plate) | 0.76 |
| Manganese Steel Strip | 0.72 |
| Duralumin (High tensile) | 0.72 |

| | |
|---|---|
| Duralumin (Soft) | 0.72 |
| Duralumin (Heat treated and aged) | 0.65 |
| Iron | |
| Steel (Chrome-Nickel Structural) | 0.62 |
| Steel (13 per cent Chrome Strip) | 0.58 |
| Steel (13 per cent Chrome Tubes) | 0.45 |
| Steel (18 per cent Chrome) | 0.35 |
| Solder | |
| Tin | |
| Brass | 0.27 |
| Al. Bronze | 0.26 |
| Gun Metal | 0.21 |
| Copper | |
| Steel (Austenitic 18-8) | 0.20 |
| Monel Metal | 0.18 |
| Silver | |
| Gold | |
| Hydrogen | |
| Carbon | |
| Tungsten | |
| Vanadium | |
| Chromium | |
| Chlorine | |
| Sulphur | |
| Oxygen | |

(To Electronegative)

Thus from the table, we would expect that in the case of a combination of zinc and low carbon steel strip that the zinc would corrode and that the steel would be protected. The difference in voltage is $1.13 - 0.79 = 0.34$. However, if, under the same circumstances, this low carbon steel strip were in combination with brass, we would expect the steel to corrode even faster than did the zinc due to the fact that the brass is more negative, the voltage difference being $0.79 - 0.27 = 0.52$.

Although the table is not complete, we know that ordinary iron must have a potential of from 0.62 to 0.65 volt. Solder and tin must lie between 0.27 and 0.35, solder being somewhat worse than tin. Copper must have a potential of approximately 0.20 volt. We do not know the approximate potential values of silver and gold, but we need not be greatly concerned about this, as there is little likelihood that these metals will soon be so plentiful as to permit their use in underwater construction of ships.



WALTER MARTIN McFARLAND

## WALTER MARTIN McFARLAND.

The old Engineer Corps of the United State Navy has furnished a number of men who have achieved success in civil life and who have been outstanding in their contributions to the advancement of engineering. Among the ablest of these was Captain Walter Martin McFarland, one of the early members of this Society, who twice served as Secretary-Treasurer, and for three years was a member of Council. He died at his home in Washington, D. C., on March 4 after a brief illness.

He was born in Washington, D. C., on August 5, 1859, and was appointed a Cadet Engineer after competitive examination in 1875, standing second in his class upon graduation from the Naval Academy in 1879. After graduation Captain McFarland had a wide experience in sea service and inspection duty. He was twice attached to the Bureau of Steam Engineering as assistant to Admiral George W. Melville, Engineer-in-Chief.

While he was attached to the Bureau in 1897, the subject of personnel of the Navy was under special consideration in connection with the proposed amalgamation of the Line and Engineer Corps. Up to this time conflict had been waged between these two branches of the Service for many years. In writing on this subject Admiral Melville said:

"Under a naval organization which was based on the needs of days when steam was only an auxiliary, but which has continued to the present, it could not be otherwise than that the varying interests of Line and Engineer Officers, with their widely distant points of view, should produce the conflict which has been waged between these branches of our Navy for more than thirty years. Discord was inevitable—the friction between the old order, fated to pass away, and the engineer, who, in great degree, represented that which was to succeed it. The Line Officer, justly proud of the past achievement of his Corps, was disposed to yield none of his military functions to the newcomer; while the Engineer, trained

in the same naval school and side by side with his brother of the Line, could not but see injustice in a system which gave him a vast responsibility in the care of the machinery of all types on the modern man-of-war, with the control, in some cases, of half her crew, and yet refused him the right to command enlisted men, classed him, despite his equal danger in action, as a non-combatant, and denied him the military title which, through centuries, has been associated with the fighting man.

"Many able and patriotic men, within and without the Navy, recognizing the danger to a military service whose house was thus divided against itself, have, time and again, made efforts until recently in vain, to find a solution of the problem which would reconcile all differences."

After years of agitation, the suggestion was made by a Line Officer, Admiral Robley D. Evans, U.S.N., that the Line and Engineer Corps be amalgamated. The Secretary of the Navy at that time, John D. Long, appointed the now famous Personnel Board to consider and report on this proposal.

Captain McFarland was made a member of this important Board and had the honor of acting as the sole sponsor for the younger men of his Corps. From the first he was one of the most active and efficient supporters of the amalgamation scheme. As a member of the Board he had the special confidence of its presiding officer, Theodore Roosevelt, then Assistant Secretary of the Navy.

In the light of present Navy organization, it is of interest to note a statement made by this Board in reporting favorably on the amalgamation proposal:

"Every officer on a modern war vessel in reality has to be an engineer whether he wants to or not. Everything on such a vessel goes by machinery and every officer whether dealing with turrets or the engine room has to do engineer's work.

"In making this change we are not making a revolution; we are merely recognizing and giving shape to an evolution, which has come slowly, but surely and naturally; and we propose to reorganize the Navy along the lines indicated by the course of the evolution itself."

During the hearings on the bill before the Naval Affairs Committee, Captain McFarland proved a powerful advocate of the measure and drew from the Chairman of the Committee the comment that "he was the best posted man they had ever examined."

After the enactment of the Personnel Bill by Congress in 1899, Captain McFarland resigned from the Navy to become associated with George Westinghouse as a Vice-President of the Westinghouse Electric and Manufacturing Company. He remained there until 1910 when he resigned to become Manager of the Marine Department of The Babcock & Wilcox Company, thus reentering the field of steam engineering for which he had earlier shown great aptitude and attachment. During his service with The Babcock & Wilcox Company it was very active in the development of marine boilers and particularly for the utilization of higher pressures and temperatures. Oil burning apparatus, which so revolutionized boiler operation in the Navy, was developed and perfected during this time. Under his management the company built the greater part of the boilers installed in naval and merchant vessels during the World War. He retired from active service on September 1, 1931, on account of poor health.

An able engineer with a keen mind and a very retentive memory, he was particularly noted for his application of common sense in engineering problems. Among his many activities, he lectured at the Naval War College, Naval Post Graduate School, and numerous engineering schools and colleges. He also contributed a number of papers before engineering societies and in the technical press, his work along this line being of inestimable value both for its technical and historical worth.

Shortly before his retirement, Captain McFarland's own wide store of common sense and his unusual ability to draw conflicting ideas and interests together, resulted in his unanimous choice for the Chairmanship of the Committee to Coordinate Marine Boiler Rules. The work of this Committee is of far-reaching importance and is one of the most outstanding contributions to marine engineering of recent times.

At the suggestion of Secretary Lamont, at that time Secretary of Commerce, this Committee was organized on December 27,

1929, for the purpose of coordinating the Boiler Code Rules adopted as standard by the American Marine Standards Committee and those tentatively promulgated by the Steamboat Inspection Service. The Committee was formed by requesting the Society of Naval Architects & Marine Engineers, the American Bureau of Shipping, the National Council of American Shipbuilders, the Steamboat Inspection Service, the American Society of Mechanical Engineers, the American Steamship Owners Association, and the American Marine Standards Committee to appoint representatives on the Committee. All responded by appointing a representative on the Committee which was later known as the Committee to Coordinate Marine Boiler Rules.

After the formation of the Committee it was agreed that an outside man should be appointed as Chairman. The unanimous choice fell on Captain McFarland. He was an ideal Chairman, his attitude in conducting the meetings being well expressed in a preamble which he prepared for the report of the Committee, a paragraph of which read as follows:

"A guiding principle from the beginning has been that the code should represent the unanimous opinion of the Committee. In other words, if differences of opinion arose, they were to be smoothed out and settled by unanimous vote. With great satisfaction the Committee can assert that this has been accomplished."

During his lifetime Captain McFarland achieved many honors and had an unusually wide circle of warm friends. Until the time of his death he took a keen interest in all matters concerning shipbuilding, engineering and the Navy. He served as a member of the Board of Visitors of the Naval Academy and as President of the Naval Academy Graduates Association of New York. In addition to his activities in the Society of Naval Engineers, he was a Past President and honorary member of the Society of Naval Architects and Marine Engineers, a Past Vice President of the American Society of Mechanical Engineers, President Emeritus of the Webb Institute of Naval Architecture, and for many years was most active in the Engineers Club of New York.

# BOOK REVIEW.

VON DER GALIOT ZUM FÜMFMASTER, by Otto Hover. Angelsachsen-Verlag G.m.b.H., Bremen, Germany. Reviewed by J. C. Niedermair, Senior Engineer (Naval Architect), Bureau of Construction and Repair, Navy Department.

The book presents a rather complete historical record of sailing ships built and operated during the period of 1780-1930.

There are apparently few new books on sailing ships in the German text as compared with those available to other nationals, particularly the English and Americans, and the author has written the book to fill a long-felt need by preparing this book in the German language.

The author discusses the various types and the gradual changes which took place throughout the period covered by the book.

The sailing records, tonnage, discussions of form and rigging are carefully presented.

A large number of references are noted, which indicate the vast amount of research work done by the author, and will be of special interest to students of the subject.

Lines are furnished, on a small scale, to show the form of the French frigates and the American and British clipper ships. Many small illustrations of sailing ships under sail and in harbor are also given.

The sailing records and other information concerning the later German ships are given in considerable detail, including tables of speed at forces of wind from 1 to 11 for several types, including five-masted, full-rigged ships.

Two illustrations, in map form, giving the average sailing days to and from the Lizard, from 1893 to 1904, are particularly interesting and informative.

# ASSOCIATION NOTES.

## ANNUAL BANQUET.

The Annual Banquet of the Society held this year on March 29th at the Willard Hotel in Washington was unusually well attended by considerably more than six hundred members and guests. Admiral William H. Standley, U.S.N., Chief of Naval Operations and President of the Society, presided and Rear Admiral Walton R. Sexton, U.S.N., of the General Board acted as Toastmaster.

The assembly was addressed by the President and the Navy policy in regard to building programs was outlined. Admiral Standley's address is given in full below.

Dr. C. F. Kettering, Vice President in Charge of Research of the General Motors Corporation, followed Admiral Standley and spoke on "Looking Ahead in Science and Engineering." This was an address of unusual interest and demonstrated that Dr. Kettering combines a keen analytical and scientific mind and abilities with a fine sense of humor. Mr. Strickland Gillilan, nationally known lecturer and humorist, closed the meeting, speaking on "Let Ket Look Ahead, I'm Scared to." It is regretted that no copies of these excellent addresses are available for printing.

Admiral Standley said:

Another year has passed since I was honored by the privilege of addressing, as your president, this society and its guests. During that year, I know that each and every one of you has followed directly or indirectly the progress of the Navy's building program with the keenest interest, as to its effect upon and the reaction upon it of the national and international situation. As to the latter, it seems appropriate to review, briefly, the effect upon the present and future of our Navy resulting from the recent conversation in London and the attendant circumstances. Though most, if not all of this has undoubtedly been followed closely by all of you through our excellent public press, yet the fact that I was privileged to play

a rather intimate part in the London conversations suggests that you may be further interested in my personal viewpoint on the conversations and the conditions which were set up at their termination.

Before an enlightened group of gentlemen such as is present here tonight, I do not need to argue about the necessity of bringing the Navy of the United States to treaty strength at the earliest practicable date, consistent with the time required to produce fighting units of the most modern and efficient design that the combined engineering talent of this country can devise, and of effectively maintaining it there. To be prepared to meet any foreign tendency to usurp one's rights and prerogatives either at home or abroad is an obvious duty of any people, or any nation, which expects and intends to survive in this modern world, to the same extent that it has always been since the beginning of the recorded history of the human race.

When the American delegation left for London we knew that denunciation of the Washington Treaty was threatened. This threat, however, was not unduly disturbing, fundamentally, because it was a matter justifiable enough under the Washington Treaty, and appeared only to signify that it would be necessary to search for and agree upon other formulae for the limitations of the world's navies to replace those contained in the Washington and London Treaties. Our delegation was, however, committed to the basic principles of these treaties, and to limitation and progressive reduction of naval armament, and we were ready to discuss terms of agreement along these general lines.

At our first meeting with the Japanese delegation their ambassador informed us that he had been directed to say that his government had definitely decided to denounce the Washington Treaty prior to December 31, 1935, and furthermore, that his government could no longer go along with the principles of the Washington and London Treaties. This statement definitely shut the doors against any discussion of purely technical matters and limitation terms in so far as our delegation was concerned. At the termination of the conversations, the situation remained exactly as it was at the end of this first meeting.

Upon adjournment, it was agreed that the British would continue negotiations through diplomatic channels, and if, as a result of these negotiations, there developed a basis which would appear

to form a suitable foundation for agreement, a conference would be called.

In this connection, it should be noted that, because of this denunciation, the provisions of the Washington Treaty calls for a conference in 1935. The London Treaty likewise, calls for a conference in 1935. It may also be noted that both these treaties have two years to run, that is, both expire on the same date, namely December 31, 1936.

### ALTRUISTIC MOTIVES FAILED.

That, briefly, gentlemen, is the present situation. Now what is, or what may be its effect upon us and our future naval policy? All of you will recall that, as a result of the Washington Treaty, the United States scrapped a large amount of new construction with an attendant direct financial loss of very considerable magnitude. We made, unquestionably, far greater sacrifices in this respect than any other nation. Five powers signed that treaty—Great Britain, Japan, France, Italy and the United States. Our representatives attempted to include in the treaty limitations on all classes of combatant vessels but succeeded only in regard to battleships, aircraft carriers and the size of heavy cruisers. However, to demonstrate our sincerity, we adopted a policy of disarmament by example. We deliberately refrained from new construction in light cruisers, destroyers and submarines. Thus, voluntarily, we practiced limitation in all classes of combatant vessels with the best of altruistic motives. We assumed that other powers might follow our example.

Our assumptions were not well founded, and our hopes were doomed to disappointment. We gradually drifted into a position of hopeless inferiority in the unlimited classes of combatant vessels, as the other powers continued building these classes unrestrictedly. An effort was again initiated to obtain limitations on these classes through further conference.

It is not necessary to dwell on the failure at Geneva and the decision by President Coolidge which resulted in our 23 cruiser building program. This building program did, however, appear to succeed where altruistic example failed, and the London Treaty of 1930 resulted. Nevertheless, only three powers were signatory to this treaty, namely, Great Britain, Japan and the United States. France and Italy accepted only certain specific provisions.

This treaty, unfortunately, did not have particularly beneficial results. First, because none of the signatory powers were entirely satisfied with the provisions of the treaty, and, second, because of the fact that the re-building of overage, tonnage, permissible under the treaties, was already underway rather extensively—even the United States was building several vessels of various types.

### A TREATY NAVY.

This was the situation when the present administration came into power in 1933 and our President initiated efforts to build the Navy to treaty strength and at the same time, used this method to improve the employment situation throughout the country and aid in business recovery. The Vinson act authorized this program and will result, if appropriations support it, in our owning a treaty Navy by 1942. Please note carefully that owning a full treaty Navy was in exact accordance with the letter and the intent of both the Washington and London Treaties, which, logically, might have been expected to continue indefinitely had not these treaties been denounced by a signatory power. We are now in the position of anticipating the ownership of a full treaty Navy six years after the treaties establishing it automatically come to an end by denouncement, unless further agreement is reached during the current year.

The treaties have still approximately two years to run. There seems no adequate reason for advocating for the future other than our present policy, namely, to own a satisfactory treaty Navy as soon as practicable and to maintain it in fully effective operation. Lacking any information to the contrary, the policies of other signatory powers may, I believe, be assumed to be the same.

I desire then to convey to you my opinion that our present naval set-up in regard to policy and building programs, fixed before the denunciation of the Washington Treaty, is, under the status quo, eminently satisfactory. However, it is, definitely, of the maximum importance, both nationally and internationally, that we do not delay nor deviate from this building program. We should follow this program exactly in our own interests as well as in the interest of maintaining the international status quo. To build beyond this program would, I believe, submit us to world condemnation for starting a naval race. May I also point out that a similar action by

any other naval power would put that power in the same unenviable position. Hence, this conjecture seems logical, that failing any further agreements, the status quo of the treaty ratios will probably continue to be followed by all signatory powers for some time after the treaties expire.

### DESIGN OF MODERN FIGHTING VESSEL.

One more subject which closely concerns all of you must be touched upon. Our present building program had, as I have stated, two objectives: first, to put us in possession of a treaty Navy as soon as practicable, composed of vessels of the best and most efficient designs that your collective brain power could devise, and, second, to aid in the relief of the country-wide unemployment situation as quickly as was humanly possible. Since we had not built, extensively, combatant naval vessels of various types for a considerable period of time, the engineering profession represented by you gentlemen here present tonight had made vast strides forward in every direction during that interval. We want—we all want—the best in naval combatant vessels, and the best is none too good for dependability in a modern naval engagement with any naval power which may be assumed to be as gifted in this modern machine age as are we. We are then between the horns of a dilemma: to build ships in all details of the most efficient design possible and, at the same time, to do so with the maximum dispatch. Add to this situation the fact that this building must also be done under the somewhat unwieldy and complicated, but nevertheless necessary, methods, laws, and regulations concerning governmental purchases, and the result is something of a problem in which all the makings of a first-class argument between all the participating parties are present.

Last year I called attention to the fact that each and every one of you can—and you did—make important contributions to the perfection of the design of the Navy's fighting ships. We depend upon you, we look to your collective efforts to produce fighting vessels second to none and superior to most of the world's navies. In a national emergency, it will be your brains that will achieve victory, while we of the Navy itself bend our utmost endeavor to translate into effective action, against an enemy, what your minds have conceived.

No more ingenious, intricate, and complicated single piece of mechanism has ever been produced by the hand of man than the modern fighting vessel. To concentrate such tremendous and economical power with a minimum of weight within the most restricted space and, at the same time, make it fully flexible and readily answerable to the will of the operator with accuracy, dispatch, and reliability is a feat of which the layman has little or no conception or understanding. It is a feat which is possible only by the best knowledge and shipbuilding experience that exist in this country today. Many of my audience here tonight have and will continue, I know, to contribute a large percentage of the technical ability and experience necessary to produce efficient fighting vessels. And for this I wish to thank you and for your loyal support of the Navy Department's efforts to obtain the best for our vessels which modern engineering permits.

### AVOID ROCKING INTERNATIONAL BOAT.

So, finally, I have two messages to leave with you. First, let us avoid rocking the international boat; no sword rattling; no swashbuckling. We must urge the adherence to our present building and replacement program and make every effort to see that it is not deviated from or delayed, insisting that funds be made available to carry it out in a logical and progressive manner.

Second, in carrying out this program, let us have patience and understanding in coordinating our efforts to achieve the maximum construction speed of the most efficient designs without recriminations or recourse to that time-wasting amusement of buckpassing, or, shall we say, dodging the buck when passed. We all have a common end. Let us achieve it with the least friction. And, most important of all, let the interest for the common good animate us insofar as it is humanly possible to the end that none of us may be accused of being actuated, exclusively, by self-interest and personal profit.

### TRIBUTE TO ADMIRAL ROBINSON.

In conclusion, gentlemen, I wish to pay a tribute to one who has been, I am sure, known directly or indirectly to all you at some time during his many years of devoted service in the field of marine

engineering design and especially in connection with electric propulsion of ships, to the development of which he contributed many years of earnest endeavor in the design division of the Bureau of Engineering—Rear Admiral S. M. Robinson, who has been chief of the Bureau of Engineering for the past four years and is soon to be transferred. I know you will be glad to have me speak for you in public acknowledgment of the great debt this society and all those interested in naval engineering design owe to Admiral Robinson for the contributions he has made in this great field. His intense and concentrated devotion and his outstanding ability in this field has been an inspiration to all of us. However, in leaving the bureau he is not lost to us and, I hope, will continue unabated his interest and his aid in the improvement of naval machinery design.

Admiral Robinson will be relieved by Rear Admiral H. G. Bowen, who has served ably as the assistant of Admiral Robinson during his tenure of office as chief of bureau. May I ask for him the same loyal support and cooperation which you have rendered to Admiral Robinson?

---

Captain N. H. Wright, U. S. N., and Captain Henry Williams (CC), U. S. N., have resigned as members of the Council of the Society, due to detachment from duty in Washington. Captain J. S. Evans, U. S. N., and Lieutenant Commander W. C. Wade (CC), U. S. N., have been appointed to fill the vacancies.

The following have joined the Society since the publication of our last previous JOURNAL:

NAVAL.

Brittan, Theodore H., Ensign, U. S. N.

Cruse, Andrew W., Lieutenant, U. S. N. R., 1901 Wyoming Avenue, N. W., Washington, D. C.

Gross, John A., Chief Carpenter, U. S. N. R., 1710 Georges Lane, Wynnefield, Pa.

Jupp, W. B., Lieutenant Commander, U. S. N. (Retired), 915 Kensington Avenue, Plainfield, N. J.

Keeley, E. L., Lieutenant, U. S. N. R., Massachusetts Schoolship *Nantucket,* Boston, Mass.

Snyder, E. B., Lieutenant Commander, U. S. N. R., care First Central Trust Co., Barberton, Ohio.

Sterzik, R. A., Lieutenant, U. S. N. R., U. S. Engineer Office, Zanesville, Ohio.

Talbert, E. Hume, Lieutenant Commander, U. S. N. R., Victor Building, 724 9th Street., N. W., Washington, D. C.

Wille, Frank J., Commander, U. S. N.

Wynkoop, Norman O., McGraw-Hill Publishing Co., 330 W. 42d Street, New York, N. Y.

Young, Nathan, Lieutenant Commander, U. S. N. R., 7518 E. 15th Street, Kansas City, Mo.

CIVIL.

Blair, Bryce W., General Electric Co., 15th and H Streets, N. W., Washington, D. C.

Brown, Edwin H., Manager, Engine and Condenser Dept., Allis-Chalmers Mfg. Co., West Allis, Wis.

Flesheim, R. S., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Grothaus, L. W., Vice-President, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Landreth, Robert N., Allis-Chalmers Mfg. Co., 621 Southern Building, Washington, D. C.

ASSOCIATE.

Bonathan, Kenneth, 335 Memorial Road, Houghton, Mich.

Sherman, Ralph A., Battelle Memorial Institute, Columbus, Ohio.